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AEROELASTICITY

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INTRODUCTION

THE author first heard the term aeroelasticity applied to the class of problems in applied mechanics involving interactions between aerodynamic and elastic forces during the days of World War II. Although it is not known exactly who coined the word, it was employed frequently during this period by both British and American authors and research workers. Examples of the latter are the papers of Collar whose ingenious "aeroelastic triangle" (1)* has since served as a valuable chart and research guide. The term aeroelasticity is, however, not completely descriptive of all the phenomena which it is ordinarily considered to encompass. It is usual to apply a definition in which aeroelasticity includes phenomena involving interactions among inertial, aerodynamic, and elastic forces as well as those involving merely aerodynamic and elastic forces. The former is often referred to as dynamic and the latter as static aeroelastic phenomena.

HISTORICAL BACKGROUND

A motivation and a pattern for research in aeroelasticity have been provided by the rapidly changing art of aircraft design. Prior to World War II, airplane speeds were relatively low, and the load requirements placed on the structure by design criteria specifications produced a structure sufficiently rigid to preclude most aeroelastic phenomena. As speeds increased, however, with little or no increase in load requirements, and in the absence of rational stiffness criteria for design, aircraft designers encountered a wide variety of problems which we now recognize as aeroelastic in origin. Although aeroelastic problems have been thought of as prominent factors in airplane design for a relatively short period of time, they have nevertheless proved troublesome in varying degrees since the beginning of powered flight. In fact, Langley and the Wrights may well have been affected to a greater extent than many modern designers. In the light of modern knowledge, it seems likely that the unfortunate wing failure which destroyed the Langley machine on the Potomac River houseboat in 1903 could be described as wing torsional divergence (2). The biplane structural configuration, with its inherent high torsional rigidity, was a fortunate feature of the Wrights' design which precluded wing aeroelastic difficulties. However, they were unable to avoid such difficulties completely, and their troubles were encountered in the design of propeller blades. In a letter to Mr. Fred C. Kelley (3), Orville Wright described how, in an attempt to make the blades broader and thinner, they encountered an unexpected loss of thrust. They concluded finally that the blades twisted from their normal pitch setting under pressures in flight. To verify this, they fastened to the blades small trailing edge tabs, which they called "little jokers," set at an angle to counteract the aerodynamic torques that were twisting the blades. After they found that the "little jokers" alleviated the problem, they gave a backward sweep to the trailing edges of their subsequent propeller blades, which served the same purpose.

Perhaps the success of the Wright biplane and the failure of the Langley monoplane was the original reason for the preference for biplanes in the early days of airplane design. This preference continued essentially until the emergence of aluminum alloys made it possible to construct cantilever monoplane wings having adequate rigidity. The period of development of the cantilever monoplane seems to have been the period in which serious research in aeroelasticity commenced. A theory of cantilever wing load distribution and wing divergence was first published in 1926 by Hans Reissner (4). Six years later a rational theory of aileron control effectiveness and reversal was proposed by Roxbee Cox and Pugsley (5). The mechanism of potential flow flutter was understood sufficiently well for design use by 1935, through the nearly simultaneous early efforts of Glauert (6), Frazer and Duncan (7), Küssner (8), and Theodorsen (9). However, few early practical designers were able to comprehend and apply the theories of the original papers, and the majority were reluctant to surrender to mathematicians the task of predicting the structural member sizes required to preclude aeroelastic difficulties.

AEROELASTIC OPERATORS

It is appropriate to commence a survey of aeroelasticity by stating the features which are common to all problems of aeroelasticity. These features relate to certain operators which form the basis for aeroelastic analyses. The process of computing the elastic deformation, ξ, of a structure subjected to external forces is one which can be represented symbolically by

$$\xi = \mathcal{S}(F_a + F_I + F_D) \qquad [1]$$

where $\mathcal{S}$ is a structural operator which transforms an external force F into the structural displacement ξ. F_a, F_I, and F_D are external aerodynamic, inertial and disturbance forces respectively. The latter force is assumed to be known explicitly, whereas the former two forces may depend in some manner upon the displacement of the system. In fact the problem is made mathematically complete by stating the dependence of the aerodynamic and inertial forces on the displacement as follows:

$$\xi = \mathcal{A}(F_a) \qquad [2], \qquad \xi = \mathcal{I}(F_I) \qquad [3]$$

where $\mathcal{A}$ and $\mathcal{I}$ are aerodynamic and inertial operators which relate the displacement of the structure with the aerodynamic

*Numbers in parentheses refer to references at end of paper.

and inertial forces respectively. When Eqs. [1], [2] and [3] are combined, we have the complete equation of aeroelasticity in the form of

$$\xi = \mathcal{S}[\mathcal{A}^{-1}(\xi)] + \mathcal{S}[\mathcal{S}^{-1}(\xi)] + \mathcal{S}[F_D] \qquad [3a]$$

It is usually assumed that the operators $\mathcal{S}$, $\mathcal{A}$ and $\mathcal{S}$ are linear. In general, it may be said that proper delineation of the aerodynamic and structural operators is the principal difficulty of applying aeroelastic theory to practical engineering problems. Both operators may be represented by integrals involving kernels called influence functions. The kernel of the aerodynamic operator is usually unsymmetric, although it may be rendered symmetric by certain simplifying assumptions. The kernel of the structural operator is symmetric as a result of Maxwell's reciprocal theorem providing ξ is a true linear displacement; however, it may become unsymmetric when ξ is represented by generalized coordinates. In general, the integral equations of aeroelasticity represented by Eq. [3a] involve unsymmetric kernels and this fact is the basis for many of the mathematical difficulties encountered in analyses. The type of mathematics problem represented by a symmetric kernel is termed self-adjoint, whereas unsymmetry of the kernel implies non-self-adjointness. It is well known that many of the convenient mathematical features of self-adjoint systems are invalid for non-self-adjoint systems. This interesting and important mathematical aspect of aeroelasticity has received some, but not nearly enough, attention by competent mathematicians. The reader is referred, for example, to the work of Fung (10), Flax (11), Lanczos(12) and Wielandt(13) for detailed treatment of this topic. A result of great practical importance of the work of Lanczos and Wielandt is the fact that the usual iterative procedures of self-adjoint systems can be used to find the eigenvalues and eigenfunctions of non-self-adjoint systems providing these eigenvalues and functions actually exist.

STATIC AEROELASTIC PHENOMENA

Analyses of static aeroelastic problems are characterized by several simplifying features. By definition, time does not appear as an independent variable and, as a result, vibratory inertial forces are not present in the equilibrium equations. Aerodynamic forces can be based upon the relatively simple steady flow results instead of the more complex unsteady flow theories. The simplest static aeroelastic problems are posed by slender wings with straight elastic axes, essentially perpendicular to the fuselage center line. When Eq. [1] is applied to the simple case of a straight nonuniform wing of semi-span l and local chord c, we have the integral relation

$$\theta(y) = q \int_0^l C(y,\eta)\, e c c_l^e \, d\eta + f(y) \qquad [4]$$

where y and η are spanwise coordinates, $C(y,\eta)$ is a symmetric torsional influence function, q is the dynamic pressure of uniform flow, e is the distance between the elastic axis and the line of aerodynamic centers, and c_l^e is the local lift coefficient which is produced as a result of the elastic twist distribution $\theta(y)$. The function $f(y)$ represents the twist distribution which one would compute by applying the aerodynamic loads on the rigid wing, that is, by neglecting the effect of elastic twist on the aerodynamic pressures. Aerodynamic theory is called on to provide a relation between incidence and lift distribution, and the form appropriate to Eq. [2] is represented symbolically by

$$\theta(y) = \mathcal{A}\,(c c_l^e) \qquad [5]$$

where $\mathcal{A}$ is a linear aerodynamic operator which operates on the lift distribution to produce the required incidence distribution. For example, in the case of strip theory, $\mathcal{A}$ is simply $1/a_0 c$ where a_0 is the local two-dimensional slope of the lift-coefficient curve. Neglect of aerodynamic span effects results therefore in a self-adjoint system. When aerodynamic span effects are taken into account, Eq. [5] assumes the form of Prandtl's lifting-line integral equation. Equations [4] and [5] form the basis for predicting the elastic twist and lift distributions, the torsional divergence speed, the aileron effectiveness, and the aileron reversal speed of slender unswept wings with straight elastic axes.

The early solutions of Reissner(4) and Roxbee Cox and Pugsley(5) were refined as flight speeds became higher. Flax(14) formulated the aeroelastic problem of a straight wing in terms of the Rayleigh-Ritz method by expressing the twist distribution as a superposition of assumed modes. Hildebrand and E. Reissner(15) later developed a procedure which takes account of aerodynamic span effects in the calculation of divergence speeds of straight wings. Exact solutions of Eqs. [4] and [5] obtained for certain planforms indicated the importance of considering these effects in divergence calculations. More recent developments in straight wing static aeroelastic problems relate to casting Eqs. [4] and [5] in matrix forms by employing aerodynamic and structural influence coefficients. The work of Lawrence and Sears(16) and Pines(17) forms the basis for application of matrices to straight wing aeroelastic problems.

As flight speed approached the speed of sound, interest shifted from the straight to the swept wing configuration. It can be shown that when streamwise segments of a slender swept wing are considered, the pertinent equations assume the same general forms as those of Eqs. [4] and [5]. In this case, when aerodynamic span effects are taken into account, Eq. [5] is usually assumed to be represented by the integral equation proposed by Weissinger(18). There is one other important difference, however, between the straight and swept wing. The structural influence function $C(y,\eta)$ in the swept wing case is no longer a symmetric function since it involves combinations of both bending and twisting. We see therefore that the swept wing aeroelastic problem involves a non-self-adjoint system even in the case where aerodynamic span effects are neglected. An important contribution to swept wing static aeroelastic analyses was made by Flax(11) when he suggested an extension of the Rayleigh-Ritz method to non-self-adjoint problems by introducing the concept of an adjoint energy function. Miles(19) suggested the use of Galerkin's method. However, casting the integral equation in matrix form and operating on the resulting equation by means of the usual methods of matrix analysis has proven to be an eminently satisfactory practical approach.

In discussing slender straight and swept wings we imply a degree of slenderness such that beam and lifting-line theories can be applied. This fortuitous state of affairs is due to the simplifying assumptions that spanwise flow components are small compared with chordwise components and that elastic variations of wing camber are negligible. The static aeroelastic problem is thus characterized by a single independent variable along the spanwise axis. If we turn attention to very low-aspect-ratio wings we find that the spanwise and chordwise components of flow (or normal stress) may, in fact, assume nearly equal proportions. It is hardly necessary to remark that the complexities of aeroelastic analyses are therefore multiplied. This comparative state of affairs is perhaps fortunate, since aeroelastic phenomena associated with slender wings are, in general, more pronounced than with low-aspect-ratio lifting surfaces. It is also generally true that the aeroelastic phenomena of most importance to low-aspect-ratio lifting surfaces occur in the supersonic speed range. The integral equation corresponding to Eq. [1] for the low-aspect-ratio wing can be expressed as

$$\alpha^e(x,y) = \iint_{\text{Surface}} C(x,y;\,\xi,\eta)\,\Delta p^e(\xi,\eta)\,d\xi\,d\eta + f(x,y) \qquad [6]$$

where $\alpha^e(x, y)$ is the distribution of local incidence due to elastic deformation, $\Delta p^e(x, y)$ is the local aerodynamic pressure which is produced as a result of elastic deformation, and $C(x, y; \xi, \eta)$ is a two-dimensional influence function which describes the incidence $\alpha^e(x, y)$ due to a unit value of $\Delta p^e(\xi, \eta)$. The explicit function $f(x, y)$ is defined in analogous fashion to the function $f(y)$ in Eq. [4]. When Eq. [6] is supplemented by the relation

$$\alpha^e(x, y) = \frac{1}{\rho U^2} \mathcal{A}(\Delta p^e) \qquad [7]$$

the problem becomes mathematically complete. Methods of solution of Eqs. [6] and [7] follow the same general pattern as the equations for slender wings. Collocation and generalized coordinate methods have been applied with some success; however, a matrix formulation in terms of structural and aerodynamic influence coefficient matrices is favored for most design studies where assured accuracy is required. For example, when Eqs. [6] and [7] are combined and then reduced to matrix form we have

$$\frac{1}{\rho U^2}[A]\{\Delta p^e\} = [C]\lceil \overline{W} \rfloor\{\Delta p^e\} + \{f\} \qquad [8]$$

where $\lceil \overline{W} \rfloor$ is an appropriate weighting matrix. Once the matrices of aerodynamic influence coefficients, $[A]$, and structural influence coefficients, $[C]$, are defined explicitly, Eq. [8] forms a basis for evaluating the static aeroelastic phenomena of low-aspect-ratio wings. It is in the definition of these matrices where the problem becomes one of exceptional difficulty. Structural influence coefficients of low-aspect-ratio plate-like wings must be dealt with analytically as a redundant assembly of beams and plates extending both spanwise and chordwise. Because of the many practical difficulties encountered in analyses of this kind, it is frequently necessary to test structural models in order to obtain the necessary structural data. Aerodynamic influence coefficients are obtained from considerations of lifting-surface theory in steady flow, a process which involves very great numerical labor. At the higher supersonic Mach numbers, beyond about 2.5 to 3.0, a simplified aerodynamic theory called piston theory (20) permits a vast reduction in the labor required to compute aerodynamic influence coefficients.

Finally, it should be mentioned in connection with static aeroelastic phenomena that several additional effects peculiar to very high-speed flight will require consideration. Loss in structural stiffness produced by the presence of aerodynamic heating can have a profound influence on all aeroelastic phenomena. Nonlinear structural behavior associated with very thin surfaces and second-order aerodynamic effects related to finite wing thickness and angle of attack are all factors which must be carefully considered. The possibility of aerothermoelastic coupling should not be completely disregarded under conditions of very rapid changes of Mach number (21).

DYNAMIC AEROELASTIC PHENOMENA

Dynamic aeroelastic phenomena are characterized and complicated by the presence of inertial and unsteady aerodynamic forces. The principal problems of interest to the airplane designer are flutter, buffeting, dynamic response effects and aeroelastic effects on dynamic stability. From the viewpoint of those whose interest is primarily applied mechanics, it is useful to commence with a unified approach to all dynamic aeroelastic problems. If we apply Eq. [1] to the dynamic aeroelastic behavior of a restrained low-aspect-ratio wing, subjected to external pressures, we obtain

$$w(x, y, t) = \iint_{\text{Surface}} C(x, y; \xi, \eta)(\Delta p^a + \Delta p^D + f^I)\,d\xi\,d\eta \qquad [9]$$

where $w(x, y, t)$ is the time history of lateral displacement, Δp^D is an explicitly defined disturbance pressure, Δp^a is the local aerodynamic pressure arising from the deformation and f^I is the inertial force per unit of wing area. The structural influence function in this case defines the linear deflection at (x, y) due to a unit lateral force at (ξ, η). The necessary supplemental relations, which correspond respectively to Eqs. [2] and [3], take on the forms of

$$\frac{\partial w}{\partial t} + U\frac{\partial w}{\partial x} = \frac{1}{4\pi\rho}\iint_{\text{Surface}} \Delta p^a(\xi, \eta) K(x, y; \xi, \eta)\,d\xi\,d\eta \qquad [10]$$

$$f^I = -\gamma \frac{\partial^2 w}{\partial t^2} \qquad [11]$$

where U is the undisturbed stream velocity, ρ is the mass density of the air in the undisturbed stream, and γ is the mass per unit of wing area. The quantity $K(x, y; \xi, \eta)$, or its inverse, is an aerodynamic influence function, usually of very complicated form (22). Equations [8], [9], and [10] form the basis for analyses of all the principal dynamic aeroelastic phenomena of a restrained low-aspect-ratio wing. In the interest of brevity we shall concentrate on flutter. Perhaps more characteristically than any other, flutter is a dynamic aeroelastic problem. Flutter can be defined as the dynamic instability of an elastic body in an airstream. Like divergence, the only air forces necessary to produce it are those due to deflections of the elastic structure from the undeformed state. We can obtain an adequate definition of the flutter properties of a system by studying the stability of infinitesimal motions. The flutter or critical speed U_F and frequency ω_F are defined, respectively, as the lowest airspeed and the corresponding circular frequency at which a given structure, flying at a given atmospheric density and temperature, will exhibit sustained infinitesimal simple harmonic oscillations. We adapt Eqs. [8], [9], and [10] to the flutter problem by placing

$$\Delta p^D = 0, \quad w(x, y, t) = \overline{w}(x, y)e^{i\omega t} \qquad [12]$$

where $\overline{w}(x, y)$ is a complex flutter amplitude distribution. The complex eigenvalue problem which results from this type of process has probably received as much or more attention than any other single problem of applied mechanics. Literally scores of papers and reports have been generated. It would be useless to recount them here, and the reader is referred to the numerous existing summaries on this subject (10, 22). It is worthwhile, however, to dwell briefly on the method which is currently employed for low-aspect-ratio surfaces. This approach involves a matrix formulation along the same lines as described in connection with static aeroelasticity of low-aspect-ratio wings. The use of influence coefficients for low-aspect-ratio flutter analyses has, however, been the subject of more intensive research and, by the use of modern digital computing machinery, very satisfactory methods have evolved (23). The matrix of structural influence coefficients remains the same for both static aeroelastic and flutter problems. The matrix of aerodynamic influence coefficients for the flutter problem must, however, be evaluated in a special way. It is often assumed that the wing planform is divided by a network of lines into a number of "aerodynamic boxes." It is assumed that each box is sufficiently small so that the pressure and downwash may be taken uniform over its area. The flutter aerodynamic influence coefficient is obtained by assuming that one box is pulsated at a given frequency with a unit downwash amplitude, all other boxes remaining stationary. There will be a uniquely determined pressure acting on each of the stationary boxes. The flutter aerodynamic influence coefficient A_{ij} is defined then as the pressure acting on the box j due to the unit downwash pulsation of the box i (24). Considerable effort has been expended by research agencies and by the aircraft companies, both in the United States and

abroad, in developing methods for computing flutter aerodynamic influence coefficients. Satisfactory practical methods appear to exist for wings in subsonic flight and for wings in supersonic flight with all supersonic leading edges (25). For wings in supersonic flight, but with subsonic edges, more research is required to obtain satisfactory practical procedures (24,26). Finally, piston theory may be mentioned as a new and promising tool for computing aerodynamic influence coefficients at appreciable supersonic speeds (20).

We have touched very briefly on some of the concepts which relate to low-aspect-ratio flutter. Flutter is, however, a very broad subject with many important facets which space does not permit us to list, let alone discuss. The reader is referred to the excellent recent survey of the flutter problem by Garrick (27). Control surface flutter and panel flutter must also be mentioned as very important flutter areas at the present time. Because of the current interest in missiles, panel flutter has received considerable recent attention. Failure of several early V-2 missiles was attributed to panel flutter, and its existence has been verified by wind-tunnel tests. Practical aspects of the panel flutter problem are still unresolved, although the basic factors which influence its incidence such as Mach number, altitude, pressure differential, panel dimensions and material of construction are fairly well known. Practical matters which require further study are the influence of buckling, thermal stresses, and nonlinear effects. Panel flutter has appeared in controlled experiments as a limited amplitude phenomena which could continue until the panel is fatigued. This phase of the problem requires further investigation (27).

It must be mentioned also that aerodynamic instabilities which fall within our definition of flutter are encountered on many familiar objects besides aircraft. The usual result is an objectionable source of noise and vibration and catastrophic failure may not always be the important factor. Common incidents of this sort are the luffing of sails, flutter of flags (28), vibration of control vanes in ventilating systems and oscillations of poorly designed weather vanes. One other example of catastrophic flutter stands out, however. This is the unstable oscillations of very flexible suspension bridges, which was brought dramatically to public attention by the self-destruction of the Tacoma Narrows bridge in a 42-mph crosswind on November 7, 1940. Actually, there has been a long history of similar undesirable oscillations and failures. Most of the bridges involved had roadbeds that were abnormally weak in torsion. Improved behavior has generally been achieved by increasing the torsional stiffness and modifying the cross-sectional shape to reduce the instability of the airloads which are developed. Potential aerodynamic theory has little value for predicting the unsteady pressures on the side trusses and roadbed of the average suspension bridge, and practically all research on flutter has involved wind-tunnel models. Two particularly extensive series of tests have been reported by Farquharson (29) in the United States and Frazer and Scruton (30) in England.

EXPERIMENTAL AEROELASTICITY

The remarks thus far have remained within the province of aeroelastic analysis. No survey of aeroelasticity would be complete, however, without at least brief mention of experimental methods. Aeroelastic experiments may be employed for research purposes or as aids to the designer. Because of uncertainties in methods of analysis they are extremely important tools in aircraft and missile development. Indeed, aeroelastic phenomena encountered at the forefront of modern design often do not yield to analysis, and, if solutions are to be obtained within a reasonable length of time, the employment of experimental methods is absolutely necessary. Aeroelastic model tests in the wind tunnel have played a major role in research and development. These tests range from purely aerodynamic tests of unsteady air forces to tests of complete aeroelastic models. Wind-tunnel tests in 1938 at the N.A.C.A. Martin Company involving a plastic flutter model by Bergen, Nagel, Miller, and Theodorsen were probably the first involving a model of an actual aircraft. Wind-tunnel tests for research purposes were pioneered by Rauscher (31) whose contributions have since formed a basis for flutter model design. Rocket testing and flight flutter testing are other experimental tools which are frequently employed. Flight flutter testing is perhaps the most challenging and important new experimental area. For somewhat more detailed surveys of experimental aeroelasticity, the reader is referred to the recent papers of Goland (24) and Garrick (27).

AEROELASTICITY FROM THE VIEWPOINT OF THE AIRPLANE OR MISSILE DESIGNER

It is relatively easy to state the factors required for minimization of aeroelastic phenomena, but it is quite another matter to put them into effect in an airplane or missile design of minimum weight. Practically every aeroelastic phenomenon can be cured or avoided by liberal additions of mass, stiffness, or damping, all of which involve additions in weight. The original selection of lifting-surface configuration is the most important design decision. In general, it can be said that low-aspect-ratio wings have a minimum, whereas slender high-aspect-ratio wings have a maximum, of aeroelastic problems.

Once the configuration is established, the design problem is one of attempting to make the airplane or missile satisfactory from an aeroelastic standpoint without adding stiffness or mass over and above that which is incorporated in the original design based on strength and other operational considerations. Design to minimize aeroelastic phenomena and, in particular, to prevent flutter is unfortunately not a process which can be reduced to simple rules. If optimum design is to be achieved, three general lines of attack must be pursued: (1) theoretical methods aided by automatic computing machinery are used to investigate a number of mass and stiffness configurations with the object of selecting the configuration of minimum weight, (2) dynamic tests of models are conducted in wind tunnels or in free flight for the purpose of establishing quantitative data such as critical speeds, and (3) exploratory proof tests of the full-scale airplane are conducted on the ground and in flight.

AEROELASTICITY FROM THE VIEWPOINT OF APPLIED MECHANICS RESEARCH

Aeroelastic problems have played a very prominent role in applied mechanics research throughout the world during the past fifteen years. This has been due in part to a strong academic interest in aeroelasticity motivated by the difficult challenge that it presented, and of course in part to the necessity of solving certain practical problems in order to fly faster. Aeroelasticity research in the past has been polarized primarily about the winged vehicle. As long as vehicles are designed to operate in the air, there will be new problems in aeroelasticity. Rotary winged aircraft, for example, present many new and challenging problems in aeroelasticity which are not satisfactorily settled. In high performance aircraft there is a growing list of aeroelastic phenomena not explainable in terms of classical linearized theories. Nonlinearities in both the structural and aerodynamic ingredients of aeroelastic theories must clearly be included in certain problems. Questions concerning the intensity and distribution of unsteady air forces on lifting surfaces, bodies and external stores arise continually in the solution of new aeroelastic problems. In the past, each aerodynamic speed range required intensive

study before questions of aerodynamic coefficients could be resolved. The hypersonic speed range presents the newest challenge.

A fresh and rigorous look at the mathematical bases for aeroelastic analyses is in order. Application of the Rayleigh-Ritz or Galerkin approach to the solution of non-self-adjoint aeroelastic problems is not rigorously correct. Development of new approaches will require research in applied mechanics at the highest level.

Response of flight structures to random aerodynamic imputs is another area in which the supply of fundamental knowledge is meager. During high-speed flight, airplanes and missiles are subjected to a wide spectrum of random disturbance ranging from atmospheric turbulence to high-intensity noise. The theory of generalized harmonic analysis provides a promising line of attack. However, research has not yet progressed to the place where design tools can be formulated.

A question of considerable interest concerns the role and importance of aeroelasticity in the foreseeable future when many of our high-speed vehicles, virtually wingless and traversing ballistic trajectories, will operate outside of the atmosphere except for brief periods of departure and re-entry. Because of the extreme speeds involved, aeroelastic problems will most certainly be an important consideration during the periods of departure and re-entry. Panel flutter and aeroelastic instabilities involving bending modes of missile bodies can be mentioned as possible areas of interest for vehicles of this type. The influence of internal pressure, fuel sloshing and damping and the thick boundary layer near the aft portions of large bodies of revolution may be mentioned as items affecting these instabilities. Finally, if re-entry of human beings is to be accomplished, thin shell bodies and lifting surfaces subjected to extreme heating and speeds will probably be involved. The aeroelastic difficulties posed by such vehicles will undoubtedly surpass anything that we have so far seen.

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23 Zaratarian, G., and Hsu, P. T., Theoretical studies on the prediction of unsteady supersonic loads on elastic wings, *WADC Tech. Rep.* 56-97, Part 1, Dec. 1955 and *WADC Tech. Rep.* 56-97, Part 2, Feb. 1956.

24 Goland, Martin, An appraisal of aeroelasticity in design with special reference to dynamic aeroelastic stability. Paper presented at the Sixth Anglo-American Aeronautical Conference, September, 1957.

25 Watkins, C. E., Runyan, H. L., and Wollston, D. S., On the kernel function of the integral equation relating lift and downwash distributions of oscillating finite wings in subsonic flow, *NACA TN* 3131, 1954; AMR **10**, Rev. 3700.

26 Pines, S., Dugundji, J., and Neuringer, J., Aerodynamic flutter derivatives for a flexible wing with supersonic and subsonic edges, *J. aero. Sci.* **22**, Oct. 1955; AMR **9**, Rev. 1561.

27 Garrick, I. E., The 1957 Minta Martin Aeronautical Lecture. Sherman Fairchild Fund Paper, Institute of the Aeronautical Sciences, no. FF-15, March 1957.

28 Thoma, D., Why does the flag flutter, Cornell Aeronautical Laboratory Translation, 1949 (From *Mitt. hydraul. Inst., Munchen* no. 9, pp. 30-34, 1939).

29 Farquharson, F. B., et al, Aerodynamic stability of suspension bridges with special reference to the Tacoma Narrows Bridge, *Univ. Wash. Engng. Exp. Sta. Bull.* no. 116, Parts I through V (Various dates up to June, 1954); AMR **5**, Rev. 3382.

30 Frazer, R. A., and Scruton, C., A summarized account of the Severn Bridge aerodynamic investigation, British N.P.L. Report N.P.L./Aero/222, 1952.

31 Rauscher, M., Report on the suitability of various materials and methods of construction for wind-tunnel models representing flutter characteristics of actual airplanes, M.I.T. Aeroelastic and Structures Res. Laboratory Report, June 1942.

"Letters to the Editor" and "Books Received for Review" now appear after the reviews.

Theoretical and Experimental Methods

(See also Revs. 754, 764, 775, 782, 788, 801, 845, 878, 910, 960, 988, 998, 1042)

Book—727. Sneddon, I. N., Elements of partial differential equations, New York, McGraw-Hill Book Co., Inc., 1957, ix + 327 pp. $7.50.

The new book of Professor I. N. Sneddon is directed to physicists and engineers dealing mainly with research work.

In its six chapters, book stresses the elementary methods of partial differential equations, giving the reader worked examples and carefully selected problems, until he acquires the minimum routine necessary to employ this powerful research instrument.

First chapter deals with ordinary differential equations of more than two variables, but only as necessary for the study of partial differential equations of first order. The second chapter is dedicated to partial differential equations of first order. Difficult matter like Cauchy's problem or the theorem of S. Kowalewska are only mentioned. Cauchy's method of characteristics, those of

Lagrange-Charpit and Jacobi are explained by elementary means, briefly and exactly. The third chapter covers second-order partial differential equations in general. A symbolic method is used for linear equations with constant coefficients and the characteristics method for such with variable coefficients. The fourth chapter deals with Laplace equations. Elementary solutions are given in various forms, boundary conditions of Dirichlet, Neumann and Churchill are considered, and unicity of corresponding solutions proved. Inversion and Green's functions are used in three- and two-dimensional potential problems. Conformal mapping is briefly reviewed.

In the following chapter on wave equation, the topics of special paragraphs are reserved to general solutions in integral form and to Green's functions for wave equations. Finite amplitude waves are also studied. The last chapter covers the diffusion equation. After a short description of the Bartels-Churchull integration method of the generalized diffusion equation, a direct proof is given for the fundamental theorem of Duhamel. Poisson and Laplace integrals are presented as elementary solutions and further examples are given for the use of integral transforms and Green's functions. A last paragraph deals with diffusion with sources.

This carefully written, highly valuable book is strongly recommended to research engineers dealing with partial differential equations. Reviewer suggests that, in a next edition, approximate methods like those of Ritz and Galerkin, and grapho-analytical ones like those of Schmidt and Liebmann should be included.

L. Hamburger, Rumania

Book—728. Legras, J., Techniques for the solution of partial differential equations (in French), Paris, Dunod, 1956, xv + 180 pp. (paperbound)

Book considers techniques which are useful in the solution of the simpler boundary-value problems involving the heat equation, Laplace's equation, and the wave equation. The classical method of separation of variables, the finite difference method, conformal mapping, the relaxation method, the method of characteristics, and the method of Green's function are considered and illustrated by means of examples. No exercises are given for the reader to solve. The material in this book is well written and organized and gives the essential information needed to cope with the more elementary problems arising in engineering.

E. J. Scott, USA

729. Albrecht, J., and Uhlmann, W., Difference method for the boundary value problem $\Delta u(x,y) = r(x,y,u)$ with curvilinear boundaries (in German), *ZAMM* **37**, 5/6, 212–224, May/June 1957.

Finite difference method is used to solve the differential equation $\Delta u(x,y) = r[x,y,u(x,y)]$ with curvilinear boundary. Detail treatment is given for mesh points connected with four, six, and eight neighboring points.

H. Lin, USA

730. Morrey, C. B., Jr., and Nirenberg, L., On the analyticity of the solutions of linear elliptic systems of partial differential equations, *Comm. pure appl. Math.* **10**, 2, 271–290, May 1957.

Authors prove that solutions of linear (strongly) elliptic systems in a domain with analytic Dirichlet data are analytic at the boundary. This fact was recently proved by Morrey for second-order systems and, using a remark of Nirenberg, is now extended to the $2m$-order systems.

These results are very important in the mathematical theory of partial differential equations, but as this journal is "an engineering magazine published mainly for the engineering profession" we cannot give a long account of methods used for their proof. We shall only say that the problems of proving differentiability and analyticity of solutions at boundary points being purely local, authors consider solutions of analytic elliptic equations in a hemisphere having zero Dirichlet data on the plane portion of the boundary and prove that solutions are analytic at all points in the hemisphere and on the plane portion of the boundary.

G. Supino, Italy

731. Vekua, I. N., Method for the solution of boundary value problems of partial differential equations (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **101**, 4, 593–596, 1955.

732. Crandall, S. H., Implicit vs. explicit recurrence formulas for the linear diffusion equation, *J. Assn. Comp. Machy.* **2**, 1, 42–49, Jan. 1955.

Book—733. Synge, J. L., The hypercircle in mathematical physics, New York, Cambridge University Press, 1957, x + 424 pp. $13.50.

The "hypercircle method" was introduced by the author and Prager in 1947 [*Quart. appl. Math.* **5**, 241–269]. An extension and improvement of the Rayleigh-Ritz method, it has been developed in numerous papers; the present volume gives a very clear, systematic exposition of the results obtained with it so far. In general, the method is applicable to problems involving two linear conditions which are orthogonally complementary with respect to a positive definite quadratic functional.

The first 124 pages of the book give the geometric idea of the hypercircle method, including an intuitive discussion of Hilbert's function space. The next 167 pages apply the method to estimate the capacity and torsional rigidity of various plane domains, especially hollow squares and hexagons. Finally, 122 pages deal with other problem types: viscous flow, elastic equilibrium, and vibration problems among others.

Most of the specific applications employ "pyramidal" (piecewise linear) functions, though this is not essential to the hypercircle method. Restricted to such functions, the method seems to the reviewer to give less precise estimates than other methods such as conformal mapping (for capacity) or finite differences. However, like Polya and Szegő's well-known "Isoperimetric inequalities in mathematical physics" [Princeton, 1951], Synge's book has a methodological interest far transcending any specific numerical calculations. It applies simple geometrical concepts to classical problems of mathematical physics in ways which should prove suggestive, to imaginative scientists, for many years to come.

G. Birkhoff, USA

734. Hutcheon, I. C., An iterative analogue computer for use with resistance network analogues, *Brit. J. appl. Phys.* **8**, 9, 370–373, Sept. 1957.

Method serves to solve the Poisson equation by means of computer as described, e.g., in AMR **8**, Revs. 1255, 2951 and AMR **9**, Revs. 2707, 3381. To maintain a current drain at each node at desired value during adjustment of all other nodes, a capacitance is used as memory device, controlling the grids of a triode. One such set (capacitance and triode) is used for each node. A scanning switch provides for correcting the condenser voltages. Method is usable also for solving problems with nonlinear parameters.

V. Paschkis, USA

735. Noon, W., Application of the analog computer to engineering problems, *GM Engng. J.* **4**, 2, 34–37, Apr.–May–June 1957.

736. Hatton, D. E., and Ward, J. R., An electronic analogue computer, *Aero. Res. Comm. Melbourne, Austral. Rep.* ACA-57, 34 pp., Sept. 1955.

737. Head, J. W., Widening the applicability of Lin's iteration process for determining quadratic factors of polynomials, *Quart. J. Mech. appl. Math.* **10**, 1, 122–128, Feb. 1957.

If an approximation is known to a real or complex root of an algebraic equation, the root can be determined from two applica-

tions of Lin's process by an adaptation of Steffensen's device (Aitken's δ^2-process), whether Lin's process is convergent or divergent, provided that the divergence is not too violent and the roots of the algebraic equation are sufficiently well separated. The basic principle used is that for a sufficiently close starting approximation and a real or complex linear divisor, successive approximations have their first differences in geometric progression. The question of finding a suitable starting approximation is not considered. Two numerical examples, one with real roots and one with complex roots, are discussed fully.

From author's summary by W. J. Carter, USA

738. Bakhvalov, N. S., Estimation of the error arising in the numerical integration of differential equations by the Adams extrapolation method (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **104,** 5, 683–686, Oct. 1955.

739. Abramov, A. A., Round-off errors in solutions for system of linear equations, *Doklady Akad. Nauk SSSR (N.S.)* **97,** 2, 189–191, July 1954.

740. Zajta, A., On iterative approximative methods (Part I) (in Hungarian), *Magyar Tud. Akad. Mat. Fiz. Oszt. Közl.* **6,** 3/4, 467–489, 1956.

741. Kloomok, M., and Muffley, R. V., Polynominal cam curves, *Prod. Engng.* **28,** 3, 196–203, Mar. 1957.

742. Marcus, L., A mathematical tool in industry: an algorithm for curve fitting by the method of least squares, *GM Engng. J.* **4,** 2, 16–21, Apr.–May–June 1957.

In their simplest form, experimental data are dependent upon two related variables X and Y which are plotted with the X values as the abscissa and the Y values as the ordinate. If the plotted points approximate a straight line, it becomes necessary to determine the coefficients of the analytical equation of the line which best fits the data. One approach to determining coefficients is the application of the method of least squares. In general, however, the dependent variable is dependent on more than one independent variable, and the form of the plot of the dependent variables versus any one of the independent variables is more complicated than a straight line. For the more general case, the *exact* form of the analytical equation to be fitted must be chosen beforehand before the classical method of least squares may be used. A lengthy iteration process must be performed in order to minimize the number of terms in the equation. To eliminate this shortcoming, a new approach to the problem of determining an equation to fit a set of experimental data was developed. The result has been a method, based upon the principles of the method of least squares, which (a) eliminates the trial and error computations required to determine the approximate minimum number of terms in the equation, (b) avoids the solution of an almost dependent set of simultaneous equations, and (c) has the advantage that any number of independent variables can be considered at the same time. This method has been successfully applied to such phases of experimental engineering as the design of fuel control systems, compressors, and turbines for turboprop and turbojet engines.

From author's summary

743. Natanzon, V. Ya., Formula for the image of a product of originals (in Russian), *Prikl. Mat. Mekh.* **20,** 5, 671–672, Sept.–Oct. 1956.

A formula is derived for the image of the product of two originals which can be generalized to the product of a higher number of originals.

M. D. Friedman, USA

744. Luchak, G., The solution of the single-channel queuing equations characterized by a time-dependent Poisson-distributed arrival rate and a general class of holding times, *J. Operat. Res. Soc. Amer.* **4,** 6, 711–732, Dec. 1956.

Paper develops the methods of solution of single-stage queuing problems characterized by a Poisson arrival rate and a general class of holding time distributions. The holding time distribution is obtained by considering "service" as involving m phases, each of which has an exponential holding time distribution characterized by a parameter $\mu(t)$. The arrival rate $\lambda(t)$ and $\mu(t)$ are continuous functions of time and possess continuous derivatives of all orders. Interest is in time-dependent solutions and rate at which the system approaches the steady state.

The general solution is developed in the vector-matrix form following the methods of Lederman and Reuter [*Phil. Trans. roy. Soc. Lond. (A)* **246,** p. 321, 1954]. Two particular cases are discussed in detail: (1) $\rho = \lambda(t)/\mu(t)$ is a constant and the holding time distribution is Pearson Type III (solutions obtained in closed form in terms of a new (Luchak ?) function $I_n^R(z)$, some properties of which are discussed); and (2) $\rho = \rho(t)$ and exponential holding times.

The methods are particularly useful in that one can obtain quasi-stationary steady-state solutions after a series of trial calculations from initial state. This is particularly useful when one is interested in deviations from steady-state solutions introduced by, say, time dependence of arrival rate.

E. Koenigsberg, USA

745. Fereday, F., Problems of the queue, *Brit. Coal Utilisat. Res. Assn. Bull.* **21,** 6, 249–254, June 1957.

746. Baker, A. G., Analysis and presentation of the results of factorial experiments, *Appl. statistics* **6,** 1, 45–55, Mar. 1957.

A systematic method of setting down and analyzing the results of factorial experiments is discussed. The method is particularly suitable for use with a desk calculating machine and is applicable to either qualitative or quantitative factors.

From author's summary

747. Vaswani, R., The aircraft assignment problem, *Aero. Engng. Rev.* **16,** 2, 64–68, Feb. 1957.

An analytic linear programming solution is described which illustrates the application of Flood's optimal assignment technique and which is basically simple to apply and can be used routinely by clerical personnel.

From author's summary

748. Shaw, R. R., Mechanical storage, handling, retrieval and supply of information, *AGARD Publications, Rep.* 50, 36 + iii, Feb. 1956.

The technical and administrative problem involved in the storage, handling, and retrieval of library information are emphasized throughout this detailed account of the present equipment used. Reference is made to previous studies and suggestions given for future research. Particular attention is paid to the need for fundamental systems studies and for fuller investigation of the requirements of the scholar. Author concludes that the problem has proceeded in piecemeal and "gadget" fashion and stresses the need for more detailed analysis of the usefulness and economic justification of each separate piece of machinery, without, however, losing sight of the problem in its entirety.

By way of practical illustration a method is suggested for making the resources of Harvard University's Lamont Library available to all colleges.

From author's summary

749. Fairthorne, R. A., Matching of operational languages in documentary systems, *AGARD Publications, Rep.* 49, 14 pp. + iv, Feb. 1956.

Clerical activities are sequences of elementary observations, identifications, and manipulations of marked objects. The basic repertories or "alphabets" of operations, as well as of marks, are finite, as are the vocabularies of permissible sequences, or "words." Such an alphabet, whether of marks or operations, and associated vocabulary is called a "script." Scripts can be represented algebraically, and any systematic spelling rules will be reflected in the algebraic structure. The linguistic parameters of scripts directly affect the capital and operational costs of using them. In general, one optimal script is needed for each clerical link, and marks and operations should be direct transliterations of this. With this generalized concept of a script, all clerical tasks, including marshalling and retrieval, can be studied as chains of transcriptions and transliterations.

Scripts can be represented algebraically and partially ordered by inclusion, which depends on possible derivation of one script from another by selection and alterations of synonymity and homonymity. Thus script inclusion involves explicitly the available clerical facilities for pattern recognition, discrimination and storage. Identification of these with suitable algebraic operations makes possible an algebra of clerical activities.

From author's summary

750. Ramo, S., The new emphasis on systems engineering, *Aero. Engng. Rev.* **16,** 4, 40–44, Apr. 1957.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 770, 771)

751. Ellis, J. R., Start-stop time of a geared system, *Engineer, Lond.* **203,** 5290, 902–904, July 1957.

Geared mechanisms are frequently considered in the design of automatic control systems, where the time to traverse the mechanism through a given angle starting from and returning to rest is a measure of the suitability of the mechanism for a particular use. Consideration is given to the selection of the gear ratio for maximum acceleration of the output shaft when the gearbox efficiency and the various rotational moments of inertia and resistances are known. The equations developed enable the performance to be calculated directly in terms of the torque obtainable from the driving motor and the angular displacement and velocity of the output member. The "effective" moment of inertia of the mechanism is shown to be different in the driving and braking conditions. Use of a separate symbol for each item of the mechanism enables the individual effects to be determined. An example is given in which the slope of the resistance curves makes the use of graphical methods of integration adivsable. From the motor torque versus output shaft speed of rotation graph the relation between time elapsed and rotational speed is obtained for both driving and braking conditions. Two methods of obtaining the "start-stop" time are shown and their relative merits discussed. The optimum time or position for the application of braking force may also be obtainable from these graphs.

From author's summary by J. N. Aguirre, Argentina

752. Aumann, G., The space sledge (in German), *ZAMM* **36,** 11/12, 433–436, Nov./Dec. 1956.

A "space-sledge" is a rigid body moving in such a way that the absolute velocity of one of its points is either (I) normal or (II) parallel to a given direction within the body. The equations of motion for a force-free space-sledge are deduced, and it is shown that in the case of spherical symmetry there are, apart from the trivial periodic solutions, only solutions with aperiodic velocities in case (I), while in case (II) solutions with periodic velocities also exist.

From author's summary by J. N. Aquirre, Argentina

753. Lifshits, Ya. G., Theory of the structure and the classification of plane and spatial groups of mechanisms (in Russian), *Trudi Rostovsk. -na-Donu in-ta s.-Kh. mashinostr.* no. 6, 47–62, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5765.

On the basis of the classification of mechanisms by I. I. Artobolevski and V. V. Dobrovol'ski, formulas have been evolved for the formation of compact plane and spatial groups of mechanisms, and for substitution in the groups of different families, of kinematic pairs of different classes.

F. M. Dimentberg, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

754. Kislitsyn, S. G., Use of the method of tensors in the theory of spatial mechanisms (in Russian), *Trudi Sem. teor. Mash. Mekh.* **14,** 54, 51–75, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5764.

The analytical method is used to determine the position of the links in spatial mechanisms, based on the utilization of spiral "affinors." These affinors are distinguished from the universally known ones in that they represent in themselves operators of transformation not of vectors, but of spirals, which, in certain conditions, can be examined as "complex" vectors. The application of spiral affinors is linked up with the operational effect on complex numbers of the form $\alpha + {}_{\omega}b$, where ω is the operation commanding the property $\omega^2 = 0$.

In examining the end point of transfer of links in spatial mechanisms it was found that the initial positional point of the links with the end point merges with the assistance of a "versor" having a complex matrix. To determine the unknown angles of rotation of the links, an affinor equation is built up. This, in the general case, in a coordinated system leads to eighteen material algebraical equations.

Examples are given of the application of the method to certain mechanisms, for which numerical results were obtained.

F. M. Dimentberg, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

755. Orlov, A. A., Almost periodic motion of a particle in the gravity field of a spheroid (in Russian), *Trudi Astron. in-ta im. Shternberga* **24,** 139–153, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4958.

The particle moves in the field of gravity of a spheroid. If the distance of the particle from the spheroid is sufficiently great, it will be possible to find the particular solution of differential equations of the motion of the particle which are infinitely close to Kepler's solution of the problem of two bodies, the gravitational point coinciding with the center of the spheroid.

These solutions analytically represent trigonometric series depending upon two arguments: the first is the true anomaly of the point in the Kepler motion indicated, and the second is proportional to the first, the coefficient of proportionality being a certain whole series arranged in negative steps of large distances of the particle from the spheroid. In all the infinite series in the solution of the problem, only those coefficients are found which increase by a degree of the inverse distance not exceeding the second.

L. N. Sretenskii, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

756. Marozova, E. P., On rotation stability of a solid body suspended by a string (in Russian), *Prikl. Mat. Mekh.* **20,** 5, 621-626, Sept.-Oct. 1956.

A homogeneous symmetric rotational solid body is suspended by a vertical string, colinear with the axis of the body's symmetry, and rotates about this axis with initial angular velocity (ω). This mechanical system is a holonomous system with five degrees of freedom. Using Lagrange's differential equations of the second kind, one obtains a system of five equations in regard to five generalized coordinates (α, ω, ψ, θ, φ). The solutions of this system are such that four angles are equal to zero but $\phi = \omega =$ const.

The stability conditions of this motion are treated by means of Lyapunov's and Tchataev's method, i.e., the function V, which is a linear combination of the first three algebraic integrals of motion, must satisty the first Lyapunov theorem about the stability of the motion of mechanical systems. The relations among the conditions are discussed. D. Raskovic, Yugoslavia

757. Frenkina, I. P., The rotation of a body of variable mass round an immovable axis (in Russian), *Trudi Tagan. rogsk. radio-techn. inta* **1,** 180-183, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5693.

Lagrange's equation of the second degree is deduced for a body of variable mass with one degree of freedom (of movement), which can be applied to the study of the movement of the cylinder of a threshing machine.

There are misprints and inaccuracies in the article; the conclusion and the equation itself [5] without additional proofs cannot be accepted as correct. A. Sh. Aminov, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

758. Bautin, N. N., Dynamic models of free clock movements (in Russian), Recollections of Alekhsandra Alekhsandrovicha Andronova, Moscow, Igd-vo Akad. Nauk SSSR, 1955, 109-172; *Ref. Zh. Mekh.* 1956, Rev. 5719.

The theory is given of free clock movements provided with a built-in escape mechanism for the escape wheel. A basic problem is shown to be the influence of friction on the period of natural oscillation. By using accurately adapted dynamic models with one and two degrees of freedom, the movements are examined of the chronometer and the free escape lever types.

As the result of the examination of the chronometer type of movement the dynamic characteristics of the movement were clarified (curves showing the dependence of the period of natural oscillation on friction at the balance staff and the turning moment on the arbor of the escape wheel) and the means required to vary these characteristics.

N. V. Butenin, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

759. Turkovsky, V. A., A variation problem in the dynamics of a particle (in Russian), *Izv. Kievsk. politekhn. in-ta* **16,** 216-228, 1954 (1955); *Ref. Zh. Mekh.* 1956, Rev. 4961.

Approximate solution of the problem of a very short period of time in the presence of the frictional force, taking into account the force of resistance of the medium proportional to the square of the velocity. G. I. Dvukhsherstov, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

760. Okhotsinskii, D. E., Theory of the motion of a body with cavities partially filled with a liquid (in Russian), *Prikl. Mat. Mekh.* **20,** 1, 3-20, Jan./Feb. 1956.

N. E. Joukowsky (1885) has investigated the motion of a solid with cavities wholly filled by a liquid and shown that all systems can be replaced by some solid body having the same mass as the systems and some moment of inertia. The problem was first discussed by Stokes (1842) and studied by Helmholtz (1860), Lubeck (1873) and Neuman (1883). The case where a cavity is partially filled was discussed first in 1950, and reports on this subject are appearing successively. Present paper is one of them.

In this case we can not replace the system by an equivalent one but we can introduce inertial characteristics of the system, analogous to mass and moment of inertia for some special motion such as impulsive motion and harmonic oscillation, and establish equations of motion utilizing them. This enables us to analyze the motion of the system under a given external force. Results are obtained for the case of a cavity in the form of a cylinder and two concentric cylinders. M. Kataoka, Japan

761. Narimanov, G. S., Motion of a solid with a cavity partially filled with a liquid (in Russian), *Prikl. Mat. Mekh.* **20,** 1, 21-38, Jan./Feb. 1956.

The equations of motion of a solid with cavities filled partially by a liquid were derived by a different method given by Okhotsinskii and others [see preceding review]. The existence and uniqueness of their solutions and the possibility of a method of reduction for successive approximation of solution are discussed. The method of reduction is applied to the case of a body with cavity of cylindrical form acted upon by a spring force, and of pendulum filled by a liquid. M. Kataoka, Japan

762. Kneschke, A., Rolling friction on a track forming line (in German), *Ing.-Arch.* **25,** 4, 527-543, June 1957.

Paper gives a theoretical solution of the motion of a wheel rolling on a thin viscous layer, situated on rigid ground. Using the assumption that the relation between pressure and velocity of the viscous layer can be described by Sommerfeld's differential equation of the hydrodynamical theory of bearing friction, in connection with rolling motion of the wheel, author derives equations for the evaluation of mutual influence between various quantities, as for example, load of the wheel, driving force, moment and power, rolling velocity, slip, thickness of the layer, deepness of the track, etc. Results obtained by calculating practical examples lack experimental proof. Most of the introduced qualitative relations can be obtained by direct considerations. V. Kopriva, Czechoslovakia

Vibrations, Balancing

(See also Revs. 801, 839, 867, 955, 957, 963, 1046, 1047)

763. Moloy, C. T., Use of four-pole parameters in vibration calculations, *J. acoust. Soc. Amer.* **29,** 7, 842-853, July 1957.

Block diagrams and the associated four-terminal (pole) networks have long been used successfully for the analysis of complex electrical systems. It is the author's intention to present a summary of the fundamentals of this four-pole technique as applied to linear mechanical vibrations and to discuss a few applications. Method is also useful for obtaining equivalent electrical circuits for mechanical systems.

First he defines the four-pole parameters for the components of the mechanical system (i.e., spring, mass, resistor, etc.), and for series and parallel connections. The method is then applied to the problems of the generalized vibration isolator, shake-table response, and shock excitation, all of which are considered as lumped constant systems; the continuum problems of wave propagation in a helical spring and a rubber block are also treated. Ad-

ditional remarks are made concerning the physical measurement of four-pole parameters.

Reviewer finds method to be extremely interesting and recommends it to those who are interested in modern methods of vibration analysis. H. N. Abramson, USA

764. Kononenko, V. O., On oscillations in nonlinear systems with many degrees of freedom, *Dokladi Akad. Nauk SSSR* (N.S.) **105,** 4, 664–667, 1955. (translated from Russian by M. D. Friedman, 572 California St., Newtonville 60, Mass., 4 pp.).

Author constructs particular solutions of systems of nonlinear differential equations with coefficients that deviate slowly from the periodic. The equations, describing oscillatory motions of a nonlinear system with N degrees of freedom, are of the form:

$$\frac{dx_\sigma}{dt} = q_{\sigma 1}(\theta, \tau)x_1 + \ldots + q_{\sigma n}(\theta, \tau)x_n + \epsilon V_0(x_1 \ldots x_n, \theta, \tau, \epsilon)$$

in which $\tau = \epsilon t$ and ϵ is a small parameter. ($\sigma = 1, 2, \ldots n.$) $n = 2N$. Author uses a method analagous to that presented in a previous paper [title source **105,** no. 2, 1955] for oscillations in nonlinear systems with one degree of freedom.

A method for solving the single-frequency oscillations in corresponding nonlinear systems with periodic coefficients is also indicated. M. L. Baron, USA

765. Leiderman, Yu. R., and Rasskazovskii, V. T., Frequencies and forms of free oscillations of a cantilever rod of variable section (in Russian), *Dokladi Akad. Nauk SSSR* (*N.S.*) no. 6, 7–12, 1954; *Ref. Zb. Mekh.* 1956, Rev. 5410.

On the basis of the theory of linear integral equations, aided by the representation of the natural functions of the nucleus by the natural functions of a rod of constant section, the frequencies and forms of the natural oscillations of the highest orders of the rod are found to have the form of a complete or truncated cone. The results of the calculations were subjected to experimental verification on a special model. I. E. Sakharov, USSR

Courtesy Referativnyi Zburnal

Translation, courtesy Ministry of Supply, England

766. Fung, Y. C., Sechler, E. E., and Kaplan, A., On the vibration of thin cylindrical shells under internal pressure, *J. aero. Sci.* **24,** 9, 650–660, Sept. 1957.

"Breathing modes" are considered of thin circular cylinders under very low internal pressures. The frequency equation is derived using conventional shell theory, and the results are compared with those of Reissner. Frequency spectra are calculated and compared with experimental results. The agreement is reasonable in view of experimental difficulties. It is shown that the lower frequencies are very sensitive to the magnitude of the pressure.

Theoretical calculations appear to be of extraordinary importance in these problems, because without them it is virtually impossible to interpret the test results.

M. Botman, Canada

767. Martin, A. I., Approximation for the effect of twist on the vibration of a turbine blade, *Aero. Quart.* **8,** 3, 291–308, Aug. 1957.

Differential equations of lateral vibratory motion are derived (again) for twisted cantilever beam in both twisted and untwisted coordinates neglecting shear and rotatory inertia. They are applied to a wide thin uniform beam of uniform twist by a perturbation method, and method is shown for calculating effect of rate of twist on natural frequencies. Author concludes that vibratory stress will be large when a stiff direction frequency equals a limber direction frequency. He continues to apply perturbation equations to nonapplicable cases, i.e., square cross-section beams, and thus draws some rather odd conclusions about twisted square rods where the twist can have no effect. Reviewer feels that his conclusions about the relative stresses in the case of equal frequencies are equally in error since again the perturbation assumptions are invalid. R. Plunkett, USA

768. Kogaev, V. P., Determination of the frequencies and forms of the natural oscillations of plates of variable thickness (blade type) (in Russian), *Trudi Mosk. aviats. tekhnol. in-ta* no. 25, 75–91, 1954; *Ref. Zb. Mekh.* 1956, Rev. 5399.

The frequencies and forms of the natural oscillations of plates of varying thickness are determined by the Ritz method. Polynomials are used as coordinating functions. They insure rapid convergence and give considerable simplification in calculating integrals from coordinating functions. In the case of a symmetrical plate, in the determination of the first three or four frequencies, a determinant of the sixth degree breaks down into two determinants of the third degree, one of which corresponds to the bending forms, the other to the torsional ones. By increasing the order of the determinant it is possible to find frequencies and forms of a higher order. The method may be applied to the calculation of blades of hydraulic turbines.

I. E. Sakharov, USSR

Courtesy Referativnyi Zburnal

Translation, courtesy Ministry of Supply, England

769. Kochin, N. E., Computation of critical velocities of a beam (in Russian), *Prikl. Mat. Mekh.* **20,** 3, 426–428, May-June 1956.

This short note, written in 1941 and found in notes of the author, now deceased, concerns vibrations of an airplane wing. Problem is simplified to that of finding forced vibration frequencies of a uniform beam, of length $2L$, simply supported at $x = 0$, and with sections at $x = L$ and $x = 2L$ constrained to move with a mass supported by springs—the mass-spring system having a given natural frequency. Solution proceeds in a manner widely known and used even in 1941. R. E. Gaskell, USA

770. Slibar, A., and Pasley, P. R., The forced lateral oscillations of trailers, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-4, 5 pp.

Single-axle, two-wheel trailer, with uniformly advancing tow-point subjected to harmonic lateral disturbing motion. Wheels have elastic tires and analysis uses linear elastic yaw connection between "foot-print" direction and wheel-plane. Slope of elastic characteristic depends quadratically on vertical load, with maximum and two zeros. A "characteristic" is established for resonant yaw response. This consists of an equilateral hyperbolic dependence between the ratios: (1) axle lateral response to tow-point lateral disturbance, and (2) forward speed to tow-point lateral speed multiplied by square of the ratio of exciting to system frequency and a slowly varying factor of configuration. For fixed excitation frequency, this hyperbolic resonant characteristic becomes asymptotic with closer coupling of trailer axis and higher speed. Elastic design data for tires are not given. Otherwise, formulas permit design evaluation. Analytical model seems to preclude instability for "reasonable" tire characteristics and geometry. P. R. Hardesty, USA

771. Lang, G., Elastic support of engines with rubber elements (in German), *ZVDI* **99,** 741–748, June 1957.

Paper is concerned with the design of rubber elements for the elastic support of motors and engines. The scope is to show the constructor, through a number of examples, the possibilities that exist to bring the amplitudes of the oscillations into correspondence with requirements. The theory of forced damped oscillations is reviewed briefly, and also the question of material damping due to hysteresis is treated. The examples are taken mainly from the automobile industry.

Reviewer can not find that the paper adds anything to the theoretical aspects of the problem, but it may be of value to the practical user of the theory. L. N. Persen, Norway

772. Mludek, H., Determination of the critical speed range of large turbogenerator system (in German), *Maschinenbau-Technik* **6,** 1, 30–39, Jan. 1957.

It has been shown for turbogenerator system supported on more than five supports (four spans) that the determination of critical speed for bending vibration according to the method known in turbodesign as the Schwerin method is not accurate, but that the Holzer method gives results which are close to experimental values. J. L. Bogdanoff, USA

773. Voronkov, N. I., Doroshenko, E. V., and Timoshenko, V. V., Vertical oscillations of a ferro-concrete arch of large span (in Russian), *Zh.-d. str.-vo.* no. 8, 25–26, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5511.

Results are given of the dynamic tests of a ferro-concrete arched bridge with simultaneous traffic over a span of 228 m. The possibility was determined of exciting resonance oscillations of considerable amplitudes by the second frequency, caused by the wheels of rolling stock passing over the rail joints. The necessity is shown of reviewing the formula for the dynamic coefficient for arched bridges. N. G. Bondar', USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

774. DeHart, R. C., Response of a rigid frame to a distributed transient load, *Proc. Amer. Soc. civ. Engrs.* **82,** ST 5 (*J. Struct. Div.*), Pap. 1956, 23 pp., Sept. 1956.

In this paper, a method for analyzing the response of a rigid frame structure subjected to a distributed lateral load of a transient nature is presented. The structure is studied from the standpoint that it is a continuous system having a distributed mass. Time-dependent relations for deflection and moment are developed and these quantities are computed for one example.

From author's summary by F. Correia de Araujo, Portugal

Servomechanisms, Governors, Gyroscopics

(See Revs. 751, 975, 993)

Wave Motion in Solids, Impact

(See also Revs. 840, 855, 881, 994)

775. Nafe, J. E., Reflection and transmission coefficients at a solid-solid interface of high velocity contrast, *Bull. seism. Soc. Amer.* **47,** 3, 205–220, July 1957.

Calculation of the fraction of the energy incident in a plane wave on a plane interface that is carried away in each of the reflected and refracted waves has received extensive treatment. Results may be found for many special cases, but most of them apply to low velocity contrasts or to angles of incidence less than critical. This paper was prepared with certain problems of the boundary between the ocean sediments and underlying rock in mind where the velocity contrast is as large as 3 to 1. Results are presented for compressional velocity contrasts of 5/2, 6/2, and 7/2. The density ratio is taken to be 2.8/2.3 in each case. Poisson's ratio was assumed to be 0.25. This value agrees well with observations for the intermediate layer in seismic refraction work at sea, but the value appropriate for the bottom of the sedimentary column may be higher.

In addition to the numerical computations for the special cases there are included also explicit expressions for the amplitudes of the displacement potentials. These expressions are useful for numerical calculations both of the fractional energy in the transmitted and reflected waves and of relative phases. The reciprocal relations are readily demonstrated with their aid.

Y. Sato, Japan

776. Barnhart, K. E., Jr., Stresses in beams during transverse impact, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-27, 7 pp.

A theory is developed for the transverse impact of spheres on elastic beams which incorporates a dynamic plastic force-indentation law and linear elastic boundary conditions. A method is devised to account for the effect of an infinite number of bending modes. Influence of various force-indentation relations on the calculated stress history is discussed and a comparison with an experimental stress curve is provided. The problem is treated under assumption of one-dimensional theory of transverse vibrations of the beam, and neglects the effect of shear, rotatory inertia, lateral beam contraction, and internal damping. Numerical solution is given in graphical representation.

K. J. DeJuhasz, Germany

777. Volterra, E., Dispersion of longitudinal waves, *Proc. Amer. Soc. civ. Engrs.* **83,** EM 3 (*J. Engng. Mech. Div.*), Pap. 1322, 25 pp., July 1957.

Author's method of internal constraints is applied to the problem of longitudinal elastic waves in rods of rectangular cross sections. Phase and group velocity dispersion curves are compared with various of the other approximate theories.

H. N. Abramson, USA

778. Gazis, D. C., and Mindlin, R. D., Influence of width on velocities of long waves in plates, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-29, 6 pp.

Discussion of velocities of propagation of long flexural and extensional waves in a plate or bar in the transition region between the states of generalized plane stress and plane strain; i.e., for arbitrary width-thickness ratios of rectangular sections. The investigations are carried out mathematically on the basis of approximate equations of motion. It is found that, for flexural waves, as width-thickness ratio increases from zero, the velocity remains close to that for generalized plane stress until quite large values of width-thickness ratios are reached, after which the velocity rises asymptotically toward that for plane strain. For extensional waves the velocity is slightly smaller than that for generalized plane stress for all width-thickness ratios larger than zero. Mathematical treatment uses first-order equations of three potentials, with Lagrange operator; this is applied to flexural and to extensional waves, and the results are given in mathematical and graphical form. K. J. DeJuhasz, Germany

779. Thiruvenkatachar, V. R., Stress waves produced in a semi-infinite elastic solid by impulse applied over a circular area of the plane face, Proceedings, First Congress on Theoretical and Applied Mechanics, Nov. 1–2, 1955, 181–188. Kharagpur, Indian Inst. of Technology.

Author considers transient stresses and displacements produced in semi-infinite, homogeneous, elastic, isotropic solid by uniform impulsive pressure over circular area of surface. Complete solution is given for Laplace transforms of components of displacement and stress. Transform is inverted to exhibit stress normal to surface, as a function of time, produced by longitudinal *P*-wave and transverse *S*-wave, and simplifications for points on axis of symmetry are noted. J. J. Gilvarry, USA

780. Hunter, S. C., Energy absorbed by elastic waves during impact, *J. Mech. Phys. Solids* **5**, 3, 162–171, 1957.

Experiments of impact between ball bearings and steel specimens showed that the relation between impact velocity and impact duration follows the Hertz theory; however, the velocity of rebound is less than the impact velocity. Author theoretically studies absorption of energy by elastic waves in an attempt to account for the loss of kinetic energy observed. Comparison between theoretical and experimental results then shows that elastic wave propagation can account for only a small part of the energy loss and hence other factors, such as viscoelastic forces, must be of primary influence in this regard.

H. N. Abramson, USA

781. Oroveanu, T., and Pascal, H., Plane wave velocity in a compressible liquid and gas mixture (in Rumanian), *Acad. Repub. pop. Rom. Comun.* **6**, 3, 419–422, 1956.

Authors take up previously studied state equation for a compressible liquid and gas mixture [title source **5**, no. 9, 1955], integrating it under assumption of isoterm motion. Obtained result is applied to determining plane wave propagation velocity in a homogeneous porous medium.

V. N. Constantinescu, Rumania

782. Goldsmith, W., An elongating string under the action of a transverse force, ASME Summer Conf., Berkeley, Calif., June 1957 Pap. 57-APM-9, 8 pp.

Author investigates motion of a flexible string of uniform cross section and density when subjected to a constant tensile force acting in the direction of increasing length. A known force ($F(t)$ also acts transversally. The resulting boundary-value problem which involves the ordinary one-dimensional wave equation is solved by the well-known method of characteristics. Solutions are obtained for the cases when the end of the string moves either at constant velocity or at constant acceleration. Numerical solutions as well as graphs are given.

E. J. Scott, USA

Elasticity Theory

(See also Revs. 774, 800, 801, 802, 803, 806, 807, 808, 809, 810, 862, 876, 993, 994, 997)

Book—783. Chien, W. Z., Hu, H. C., Lin, H. S., and Yeh, C. Y., Theory of elastic cylinders in torsion (in Chinese), Peking, China, Science Publication Association, 1956, 492 pp.

The first two chapters are devoted to a resume of the classical, Saint-Venant torsion theory and the techniques of solution by conventional as well as complex variable methods. The well-known solutions for torsion of bars of elliptical, triangular, and lemniscate-type cross sections are reproduced. The various known problems involving the torsion function in the form of polynomials are also presented.

The third chapter presents the usual series solutions for the torsion of bars of rectangular and sector-like cross section, as well as solutions for circular bars having semicircular cut-outs and keyways around the boundaries.

The fourth chapter is devoted to collecting known results due largely to Stevenson, Ghosh, and Sokolnikoff regarding solutions by complex variable theory of the torsion problem for bars of cardoid and half-lemniscate shape, as well as circular contours with radial cuts. The fifth chapter presents known complex variable-type solutions for angle-shaped shafts and shafts in the form of channels and Z-bars. These solutions are due largely to Hay, Seth, and Sokolnikoff.

The sixth chapter presents material to be found previously only in the Russian or Chinese literature. This centers around truncated power series approximations of the torsion function for bars of rectangular, hollow square, airfoil-like, parabolic, and scalene triangular cross sections. Bars of angle-shape and trapezoidal forms as well as circular shafts with centrally located square holes are similarly treated. Lastly, the torsion of hexagonal bars with centrally placed hexagonal cut-outs is considered.

The seventh chapter collects the well-known work of Southwell, Shaw, Allen, and Shortley regarding numerical relaxation-type approximate solutions to bars of various irregular contours. The next chapter presents certain material not previously to be found in the literature: this time pertaining to torsion of bars of variable diameter. For example, a new power series solution for the torsion of a bar of truncated conical shape is offered. Also, this chapter collects many known solutions concerning torsion of bars of circular cross section but containing various shape holes running through the bar in a direction normal to the longitudinal axis of the bar. The last chapters are concerned with bringing together almost all known experimental data obtained by the membrane analogy for a large variety of irregular cross sections. The book closes with a resume of existing knowledge obtained by the hydrodynamic analogy as well as electrolytic tank methods.

The authors have done a splendid piece of work in bringing together almost all existing knowledge to be found in the various Western and Eastern languages pertinent to this rather specialized area of elasticity theory.

W. A. Nash and C. J. Lung, USA

784. Chattarji, P. P., A note on torsion of circular shafts of variable diameter, *J. appl. Mech.* **24**, 3, 477–478, Sept. 1957.

Certain stress functions in form of polynomials have been obtained for various curves forming generating surface of shaft.

From author's summary by A. M. Wahl, USA

785. Martin, A. I., On a formula for the torsional rigidity of thin symmetrical sections, *J. Math. Phys.* **36**, 1, 20–25, Apr. 1957.

Griffith and Taylor obtained one approximate formula for the torsional rigidity C of thin symmetrical sections, the equation of the boundary curve being $y = \pm b(x)$, where $-a \leqslant x \leqslant a$. Author considers this formula as a direct consequence of Saint-Venant's theory of torsion and shows that it gives a value in excess of the true value of C. If the function $b(x)$ is the integral of its derivative and vanishes at $x = \pm a$, author establishes a lower and upper bound for the error.

G. Sestini, Italy

786. Das, S. C., On the elastic distortion of cylindrical composite bars due to frictional forces on their curved surfaces, Proceedings, First Congress on Theoretical and Applied Mechanics, Nov. 1–2, 1955, 113–116. Kharagpur, Indian Inst. of Technology.

Paper deals with the torsional problem of a circular cylinder, stiffened with a longitudinal round bar of a different material under uniform shearing stresses on the outer curved boundary caused by a kind of frictional forces. Using cylindrical coordinates, author expresses displacement v in terms of modified Bessel functions I_1 or K_1, and of three constants whose values are obtained from boundary conditions.

E. Fliess, Argentina

787. Neou, C. Y., A direct method for determining Airy polynomial stress functions, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-2, 4 pp.

Expressing the Airy stress function in the form of a double infinite power series of rectangular coordinates, author has developed a direct method for determining the unknown coefficients based only on the compatibility and boundary conditions. Two practical examples, solutions of which are finite and known, are solved. Possibility of application of this method in the presence of more complicated loadings will probably be limited due to conditions of convergence of bounded infinite series.

V. Kopriva, Czechoslovakia

788. Horvay, G., Saint-Venant's principle: A biharmonic eigenvalue problem, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-21, 6 pp.

Author confidently groups the various investigations of the Saint-Venant principle into three categories: (1) The work of Saint-Venant, Boussinesq, Goodier; (2) the papers of von Mises and Sternberg; (3) his present investigation, in which the principle is formulated in terms of a plane-stress problem for a semi-infinite, symmetric, truncated wedge loaded by self-equilibrating components of traction along one edge and traction-free along the lateral edges.

Reviewer diffidently ventures to add a fourth category containing a paper by B. A. Boley, entitled "Some observations on Saint-Venant's principle," [Columbia Univ. Tech. Rept. no. 10, July 1957, Contract Nonr-266(20)], in which a general form of the principle is given as a property of elliptic differential equations.

H. Deresiewicz, USA

789. Lianis, G., and Ford, H., An experimental investigation of the yield criterion and the stress-strain law, *J. Mech. Phys. Solids* **5,** 3, 215-222, 1957.

Necking modes of notched strips are used to establish the yield criterion and stress-strain rate relation as suggested by Hill [AMR **7,** Rev. 1096]. Experimental details follow Hundy and Green [title source **1,** 16, 1954]. Material used is commercially pure aluminum very lightly rolled at liquid air temperature. It is virtually non-hardening and hence undergoes sharp necking. Material approximates to von Mises' criterion and to the relation $\mu = \nu$ in terms of Lode's variables.

J. F. W. Bishop, Scotland

790. Supino, G., Models of solids (in Italian), *Energia elett.* **33,** 10, 1036-1047, Oct. 1956.

Author describes the deformation of different materials used in building construction. Further, basing his views on the relations of statics, he gives the conditions of similarity both for elastic and plastic fields.

P. Franke, Germany

791. Horvay, G., and Hanson, K. L., The sector problem, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-30, 8 pp.

On the basis of the variational method, approximate solutions

$$f_k(r)h_k(\theta),\ \ f_k(r)g_k(\theta),\ \ F_k(\theta)H_k(r),\ \ F_k(\theta)G_k(r)$$

of the biharmonic equation are established for the circular sector with the following properties: The stress functions $f_k h_k$ create shear tractions on the radial boundaries; the stress functions $f_k g_k$ create normal tractions on the radial boundaries; the stress functions $F_k H_k$ create both shear and normal tractions on the circular boundary, and the stress functions $F_k G_k$ create normal tractions on the circular boundary. The enumerated tractions are the only tractions which these function sets create on the various boundaries of the sector. The factors $f_k(r)$ constitute a complete set of orthonormal polynomials in y into which (more exactly, into the derivatives of which) self-equilibrating normal or shear tractions applied to the radial boundaries of the sector may be expanded; the factors $F_k(\theta)$ constitute a complete set of orthonormal polynomials in θ into which shear tractions applied to the circular boundary of the section may be expanded; and the functions $F_k'' + F_k$ constitute a complete set of nonorthogonal polynomials into which normal tractions applied to the circular boundary of the sector may be expanded. Function tables, to faciliate the use of the stress functions, are also presented.

From authors' summary by H. Mii, Japan

792. Hodge, P. G., Jr., and Papa, J., Rotating disks with no plane of symmetry, *J. Franklin Inst.* **263,** 6, 505-522, June 1957.

Authors treat elastic case of rotating disk of variable thickness and having axial symmetry but with no plane of symmetry perpendicular to axis of rotation. Basic differential equations are reduced to two simultaneous linear equations for two stress functions, and analytic solution is given in closed form for case where thickness is power function of radius. Numerical method of solution based on generalization of Manson's method, and iteration method are also described; results are compared with analytic method for particular example. It is concluded that iteration method has advantages from computational standpoint.

A. M. Wahl, USA

793. Mader, F. W., Calculation of orthotropic plate subjected to distributed load, boundary bending moments and boundary deflections (in German), *Stahlbau* **26,** 5, 131-135, May 1957.

Using one Fourier series as assumed function for each fundamental interval, all unknown coefficients are obtained from boundary conditions of simply supported, orthotropic rectangular plate and from conditions at transition from one fundamental interval to another. Extensions of calculations are indicated for plates which are simply supported at two opposite edges and alternatively built-in, continuous, or free at other edges. An application of formulas is given.

From author's summary by S. T. A. Odman, Sweden

794. Horvay, G., Some aspects of Saint Venant's principle, *J. Mech. Phys. Solids* **5,** 2, 77-94, Mar. 1957.

The aspects discussed refer to plane stress problems for rectangular regions and the semi-infinite plane. For a semi-infinite rectangle loaded along the finite edge by self-equilibrating quadratic normal traction or cubic shear traction the stress decay is found to be exponential. Graphs are given for the decay of the two normal stress components and the shear stress in terms of the distance from the loaded edge. Since Poisson's ratio ν has some effect, stress distribution profiles are given for $\nu = 0.3$ and $\nu = 0.5$. These results are obtained by an approximate variational stress function approach developed previously by the author [AMR **6,** Rev. 3018].

The aforementioned variational approach is also applied to a finite rectangle with aspect ratio 2 and the larger side subject to self-equilibrating tractions of the type considered for the semi-infinite rectangle. Graphs give the dependence of normal and shearing stress on the distance from the loaded edge. Values of $\nu = 0.3$ and $\nu = 0.5$ are again considered.

The semi-infinite plane is analyzed with the help of Muskhelishvili's complex potentials. It is found that, for typical self-equilibrating loadings, the stress decay follows the law of integral powers and that the decay is slower for shear than for the corresponding normal stress edge loading. Finally, a triangularly distributed self-equilibrating shear stress distribution with a discontinuity in the middle is assumed acting along the finite edge of a semi-infinite rectangle. Its decay is explored with the analytical help of functions previously tabulated by Horvay and Born [*J. Math. Phys.* **33,** p. 360, 1955].

Reviewer points out that the variational results for semi-infinite rectangle are superseded by a rigorous solution submitted earlier for publication by the author [ASME Pap. no. 57-APM-21]. Moreover, the paper is heavily dependent on other publications of the author to the point that its reading is more difficult than is justified.

G. A. Zizicas, USA

795. Goodier, J. N., Thermal stresses and deformation, *J. appl. mech.* **24,** 3, 467-474, Sept. 1957.

Paper is one in the "Design data and methods" series appearing regularly in the *J. appl. Mech.* and so it contains generally previously published results; some of the results, however, are taken from a forthcoming publication by Professor Goodier. Paper is a

"revision and expansion" of an earlier similar contribution by the same author [*J. appl. Mech.* 1937]. The revision covers 34 different types of problems against 14 in the original; the number of references has been increased from 9 to 35. The present-day lively interest in this field can be judged from the fact that 20 of the references appeared after the second edition of "Theory of elasticity" by Timoshenko and Goodier (in 1951)!

The information is set out clearly and concisely; it should serve well to satisfy the aims of the "Design data and methods" series.

(Two minor errors are noted: Case 9 is a special application of Case 8—not 7 as stated; and a typographical error on the right hand side of equation (29): for $\partial\Delta T$ read $\alpha\Delta T$.)

G. Sved, Australia

796. O'Sullivan, W. J., Jr., Theory of aircraft structural models subject to aerodynamic heating and external loads, *NACA TN* 4115, 48 pp., Sept. 1957.

Similarity rules are formulated for model and prototype of an aircraft deformed and stressed by its aerodynamic heating as well as aerodynamic loads. Orthodox methods (π-theorem) of dimensional analysis are employed, but some statements remain obscure to reviewer. Author concludes that similarity of model is possible except as to angular motion.

J. N. Goodier, USA

797. McDowell, E. L., and Sternberg, E., Axisymmetric thermal stresses in a spherical shell of arbitrary thickness, ASME Summer Conf. Berkeley, Calif., June 1957. Pap. 57-APM-14, 5 pp.

Authors obtain the temperature field in the form of solid spherical harmonics by solving steady-state heat-flow equation under arbitrary axisymmetric distribution of surface temperature. Thermoelastic equations are solved with the obtained temperature field, and thermal stresses and displacements for a solid sphere and for a spherical cavity are obtained in the form of infinite series of which the convergence is discussed. Numerical results for shell with two spherical boundaries maintained at two different temperatures are worked out.

D. N. Mitra, India

798. Nowacki, W., State of stress in an infinite and semi-infinite elastic space due to an instantaneous source of heat, *Bull. Acad. Polonaise Sci. Cl. IV* **5**, 2, 77–86, 1957.

Employing the so-called thermoelastic potential, author presents the solution of the first of the two title problems in Cartesian and spherical coordinates.

For the semi-infinite space whose surface is free of stress and is kept at zero temperature, the solution for the thermoelastic potential has to be supplemented by the appropriate Love displacement function. The latter appears in the form of a double Fourier integral.

The case of zero displacements on the surface of the half-space is treated in a similar way.

The results represent Green's function for the thermal stress distribution in the infinite and semi-infinite elastic body. In the latter case they are probably too complicated to be of practical value.

H. Parkus, Austria

799. Peters, G., The elastic shrink fitting (in German), *ZVDI* **99**, 2, 63–66, Jan. 1957.

A survey of formulas for elastic shrink fittings. Design formulas and graphs are given.

J. W. Cohen, Holland

Experimental Stress Analysis

(See Revs. 789, 838)

Rods, Beams, Cables, Machine Elements

(See also Revs. 751, 765, 772, 776, 783, 784, 785, 786, 787, 795, 813, 815, 816, 825, 828, 836, 843)

800. Woinowsky-Kreiger, S., Theory of oblique grids (in German), *Ing.-Arch.* **25**, 5, 350–358, July 1957.

Author shows that for a doubly symmetrical grid with oblique members one can use the differential equation for deflection of an orthotropic plate. Assumptions made are: (1) Spacing of members is sufficiently small. (2) Members have flexural as well as torsional rigidity. Joints are able to carry bending moments and torques as well as lateral loads without slip. (3) Spacing and rigidity of members are constant and equal.

For rectangular grids freely supported along circumference, bending moments are not zero at ends of each oblique member, but resultant bending moment of two members meeting at boundary is zero. Bryan's solution is valid for the anisotropic plate representing an elliptical grid with clamped edge. Uniform hexagonal grids with members in three directions and symmetrical but otherwise undefined boundary behave like isotropic plates. The solution for a freely supported equilateral triangle is especially simple.

G. Vedeler, Norway

801. Mohan, R., Some simple problems of flexure, Part I, *ZAMM* **36**, 11/12, 427–432, Nov./Dec. 1956.

Flexure problems have been solved for uniform beams having (1) a horse-shoe-shaped section bounded by two confocal ellipse and a portion of minor axis and (2) a section bounded by a parabola and a straight line. In both cases, it is assumed that the terminal loads act symmetrically at right angles to the straight edges.

S. C. Das, India

802. Nowinski, J., The torsion of a bar with cross section in the form of an annular sector, one cross section remaining plane (in Polish), *Arch. Mech. stos.* **9**, 1, 73–87, 1957.

A three-dimensional problem of torsion of a bar with an open cross section is considered, one of the end cross sections not being allowed to warp. Consequently, longitudinal stresses appear, so that to the classical solution of Saint Venant a self-equilibrated system should be added, enabling the condition of hampered warping to be realized. Of the four parameters of the self-equilibrated system, three are determined by means of the principle of least-square deviation of the resultant warping (obtained as a result of superposition of the classical system and the self-equilibrated system). For the remaining parameter the variational principle of Castigliano is used.

The values of the parameters for the entire useful range of variability of relative thicknesses, $\alpha = \delta/r_0$, are given in the form of tables and diagrams. A numerical example for $\alpha = 0.1$ and $\nu = 0.3$ is presented. It follows that the stress of the self-equilibrated system in the neighborhood of the fixed end is of the order of the Saint-Venant stress. The resultant shear stress in the middle of the longer of the curved sides exceeds the Saint-Venant stress by about 50%, the normal stress being 1 2/3 times as high as the maximum classical shear stress.

An approximate stress function and, also, variational principles being used, the solution is of an approximate character.

J. Naleszkiewicz, Poland

803. Itow, T., Elastic and plastic state of stress around a deep circular shaft, *Technol. Rep. Osaka Univ.* **5**, 349–355, Oct. 1955.

Paper deals with elastic and plastic stress distribution around a deep circular shaft, and the ultimate depth for which the shaft may be considered stable without a lining. Uniform stress distribution at constant depth is assumed, as well as that material around the

shaft yields when the octahedral shearing stress reaches critical value given by a function of mean normal stress.

From author's summary by A. Balloffet, USA

Plates, Disks, Shells, Membranes

(See also Revs. 766, 768, 778, 792, 793, 795, 797, 817, 818, 819, 831, 832, 845, 852, 957)

Book—804. Oniashvili, O. D., Certain dynamic problems in the theory of shells (in Russian), Moscow, Academy of Science, 1957, 196 pp. 9 rubles.

To the best of this reviewer's knowledge this book represents the first book on shell theory to be devoted almost exclusively to the field of shallow shells. In the first chapter, author presents the well-known differential equations governing the behavior of thin elastic shells originally presented by Vlassov in 1944. In the second chapter he presents the application of these equations to the free vibrations of a cylindrical shell having simply supported ends. This is followed by a detailed treatment of the free vibrations of an arbitrary shallow shell, provided only that the Gaussian curvature is everywhere positive. Next the natural frequencies of a thin shallow spherical segment are determined.

The next chapter introduces variational methods, and several problems involving shallow shells having specified principal curvatures at all points together with boundaries having a rectangular projection upon the shell base plane are considered. Both the internal forces as well as natural frequencies are determined. A number of conditions of edge fixity are considered. Problems involving roof shells in the form of continuous shallow cylindrical panels subject to uniform load are treated.

The fourth chapter is devoted to forced vibrations of shallow shells. Cylindrical panels subject to pulsating axial forces as well as spherical shells subject to pulsating concentrated forces are treated in detail.

The fifth chapter investigates the effects of the inclusion of nonlinear terms in the governing differential equations, and the deformations of a cylindrical panel subject to uniform normal load are determined. It is shown that, for sufficiently large deflections, the linear theory may be as much as 16% in error.

The sixth chapter treats the deformations present in shallow shells having rectangular base projections and subject to combined normal load and edge loadings in the plane of the shell middle surface. Application of these results to roofs composed of continuous prismatic segments such that the cross section appears as a series of broken-line segments is discussed in detail.

The book concludes with a seventh chapter devoted to experimental verification of these results. Strain measurements indicated by electric strain-gage techniques as well as experimentally determined natural frequencies are shown to be in excellent agreement with the predictions of theory.

Much of the work in this book has been presented in the form of numerous papers by Prof. Oniashvili during the past six or seven years. In the book he has skillfully woven together his own contributions as well as the work of many other investigators to form an excellent treatise on shallow-shell theory. The bibliography lists 71 papers in several Western languages as well as Russian.

W. A. Nash, USA

805. DeSilva, C. N., Deformation of elastic paraboloidal shells of revolution, *J. appl. mech.* **24,** 3, 397–404, Sept. 1957.

P. M. Naghdi's theory [*Quart. appl. Math.* **15,** 41–52, 1957] is applied to deformation of thin elastic paraboloidal shells of revolution with uniform thickness. Solution, following scheme given by Naghdi and valid at apex of shell, is obtained by asymptotic integration. Special problem of shell clamped at edge and loaded uniformly over small region about apex is solved and results compared with those of classical theory of H. Reissner and E. Meissner. Details of solution are difficult to follow.

F. K. G. Odqvist, Sweden

806. DeSilva, C. N., and Naghdi, P. M. Asymptotic solutions of a class of elastic shells of revolution with variable thickness, *Quart. appl. Math.* **15,** 2, 169–182, July 1957.

Authors utilize the differential equations developed by E. Reissner [**AMR 3,** Rev. 229] and themselves [**AMR 8,** Rev. 1634] to investigate the elastic deformations of a certain class of thin shells of revolution of variable thickness. Only axisymmetrical deformations are considered. The method of asymptotic integration due to Langer is employed to investigate toroidal shells and ellipsoidal shells. In both treatments the special cases of shells of uniform thickness are found to be in agreement with known results due to Clark ["On the theory of thin elastic toroidal shells," *J. Math. Phys.* **29,** 146–178, 1950] and the authors [**AMR 9,** Rev. 1054], respectively. Paper concludes by offering the special form of these solutions for the case of shallow shells of revolution. For the shallow paraboloidal shell the solution is shown to be equivalent to an earlier one due to E. Reissner [AMR **3,** Rev. 229].

W. A. Nash, USA

807. Schwarze, G., General theory of shells (in German), *Ing.-Arch.* **25,** 4, 278–291, June 1957.

The general case of deformations of a thin shell having an arbitrary middle surface configuration is treated. Displacements, curvatures, strains, and potential energy are formulated entirely in tensor notation. Second-order terms required to consider buckling of the shell are retained throughout the treatment. Equilibrium equations are presented, a nonlinear material behavior is postulated, and the total potential of the system is presented in tensor form for an arbitrary thin shell. The method of the total potential is indicated, but no examples are presented.

W. A. Nash, USA

808. Knowles, J. K., and Reissner, E., A derivation of the equations of shell theory for general orthogonal coordinates, *J. Math. Phys.* **35,** 4, 351–358, Jan. 1957.

Authors extend the earlier work of E. Reissner [*Amer. J. Math.* **63,** 1941] to obtain the differential equations of the linear theory of thin elastic shells. In the present treatment, an arbitrary orthogonal system of coordinates on the middle surface of the shell is employed, whereas in the former study the coordinates coincided with the lines of curvature. Love's first approximation is employed throughout the investigation. The earlier study made use of the fact that the lines of curvature together with the normals to the middle surface form an orthogonal system of coordinates in space. All other orthogonal systems on the middle surface, together with the normals to the surface, form nonorthogonal systems of coordinates in space. The essential point of the present derivation is the avoidance of the use of oblique space coordinates and of the notion of stress and strain referred to such oblique coordinates.

W. A. Nash, USA

809. De Schwarz, Maria Josepha, The flexural effects of forces acting upon the transverse edges of right circular shells (in Italian), *Cons. naz. Ricer.* no. 453, 51–55, 1956.

The general case of a sheet of uniform thickness bent into a single-curved surface of revolution and subjected to loads (forces and moments) along its transverse edges is analyzed. The solution handles open as well as closed surfaces. The displacements

(strains), neglecting Poisson's effect, consist of the addition of a homogeneous term to a nonhomogeneous component. In the case of open surfaces, a third term accounting for the forces along the longitudinal edges is added. A cylinder closed at one end and filled with a given liquid is also considered.

J. P. Vidosic, USA

810. Korolev, V. I., Thin double-layer plates and shells (in Russian), *Inzbener. Sbornik, Akad. Nauk SSSR* **22**, 98–110, 1955.

Layers of uniform thickness are made of different elastic and isotropic materials. Bond at contact surface is perfect, and deformation is continuous across total thickness δ. Usual assumptions ($\delta/R << 1$, Kirchhoff's $E_1/E_2 \leqslant 10$-15, stress across δ negligible) are made.

Strains and curvatures in neutral surface are expressed (first approximation) through curvilinear coordinates. Position of neutral surface is found. Stresses are related to strains (usual two-dimensional) and integrated over δ. Relationships between normal forces and strains, couples and curvatures, respectively, can be reduced to classical form provided "over-all" moduli of elasticity E and of rigidity D, and "over-all" Poisson's ratio μ, are introduced.

Equilibrium equations are set in terms of forces and couples. They do not differ from corresponding equations for thin plates and shells, except that E, D, and μ are replaced by over-all parameters. Thus, known results of classical thin plates and shells theory can be transposed.

In particular, author examines problem of thermal stresses. Again, similarity exists. Also problem for stability analysis, for which are listed some known formulas.

In order to check accuracy of this theory, stresses are calculated for circular plate and cylindrical shell, using both exact and approximate theories. Results are tabulated; agreement is very satisfactory. Limitations of approximate theory are indicated.

G. H. Beguin, Switzerland

811. Chapman, J. C., and Slatford, Jean E., Bending of plating with widely space stiffners, Instn. mech. Engrs., Prepr., 11 pp., Nov. 1956.

Simplified analysis of bending of plate with stiffeners examines specifically the effect of plate curvature in the stiffener direction upon the out-of-plane bending of the plate and hence on the stresses in the plate. Under certain conditions strong effect is indicated, and experimental measurements are in good agreement with the calculated stresses.

G. W. Housner, USA

812. Karas, K., Deformation of circular and ring membranes under hydrostatic pressure (in German), *Ing.-Arch.* **25**, 5, 359–380, July 1957.

Under the action of a uniformly distributed hydrostatic pressure, four kinds of circular membranes are analyzed: (a) full circular membrane; (b) ring membrane with a fixed rigid inner circular plate; (c) ring membrane with free moving inner circular plate, (d) ring membrane with elastically connected inner circular plate.

To obtain from the linear membrane theory a good approximation, the pressures and the resulting deflections are superimposed. First the symmetrical, then the antisymmetrical loading with the corresponding deflections are calculated.

All solutions related to the determination of the deflection surface are in closed form. All equations and their solutions are very clearly indicated. For illustration, many diagrams and tables have been prepared. Four examples show the practical procedures for numerical evaluation of the formulas.

W. Ornstein, USA

Buckling Problems

813. Clark, J. W., and Jombock, J. R., Lateral buckling of I-beams subjected to unequal end moments, *Proc. Amer. Soc. civ. Engrs.* **83**, EM 3 (*J. Engng. Mech. Div.*), Pap. 1291, 20 pp., July 1957.

Paper reports an experimental investigation into the elastic and inelastic lateral buckling of aluminum alloy "I" beams with various ratios of the applied end moments. The experimental results are compared with the theoretical method of Salvadori [AMR **8**, Rev. 2325] modified by using the tangent, secant, or a reduced modulus in the plastic range. Author suggests that current design specifications could be modified to take approximate account of the greater allowable stresses when the moment distribution is not constant.

P. C. Dunne, England

814. Boyce, W. E., The plastic bending of an eccentrically loaded column, *J. aero. Sci.* **24**, 5, 332–338, 362, May 1957.

To explain discrepancies between observed buckling loads and the classical theory, a rigid-plastic body is assumed, i.e. elastic effects are neglected and flexibility is concentrated to a single element of infinitesimal length and then extended to a wholly flexible bar. In both cases a sudden stiffening effect is found in accordance with experiments.

F. Schultz-Grunow, Germany

815. Krishnan, S., and Tewari, S. G., Buckling behaviour of the compression flange of a wide-flanged beam, *J. aero. Soc. India* **9**, 2, 15–27, May 1957.

Paper presents buckling stresses for flange of beam in which flange is sufficiently wide to have substantial decrease in stress with distance from shear web. Computations are made using one term in a double trigonometric series for the deflection function, except in one case where two terms are used. Stress distribution is described by two exponential functions. An energy method is used to obtain the solution. Results are presented in the form of tables for ratios of flange width to beam length of 0.50 to 5.0. Also presented are charts of nondimensional buckling stresses as a function of nondimensional beam length.

S. Levy, USA

816. Cattin, A., A possible kind of elastic instability of beams (in Italian), *G. Gen. civ.* **95**, 4/5, 289–302, Apr./May 1957.

Author solves problem of lateral buckling of rectangular beams. Elastic instability of built-in cantilever and of beams built-in at both ends, with narrow cross section, with vertical uniformly distributed load on upper edge and own weight on symmetry axis is studied. An approximate solution is found, using Rayleigh-Ritz method. This problem has been previously solved by Butty ["Pandeo," E. Butty, Buenos Aires, 1943], who also gives solution of nonuniformly distributed eccentric loads in beams of nonconstant cross section, and in I-beams.

H. Fernandez Long, Argentina

817. Pfluger, A., Buckling problem of orthotropic plates with hollow stiffeners (in German), *Z. Flugwiss.* **5**, 6, 178–181, June 1957.

Author's earlier investigations [AMR **2**, Rev. 180 and **9**, Rev. 679] give good start to deduce buckling load in following case. A rectangular plate simply supported at all edges is reinforced by stiffeners of closed hollow section parallel to one edge, but only at one side of the plate. Load is assumed as uniformly distributed compression parallel to stiffeners. There follow three simultaneous differential equations for displacements of middle plane in all three Cartesian coordinate directions. They are fulfilled in the considered case by a simple statement with

unknown constants; the coefficients determinant of them must vanish, yielding the buckling condition. Numerical evaluations show that practically only one half wave in each direction will appear, and remarkable increase of buckling load by torsional rigidity, especially if plate dimensions are larger in direction of stiffener.

W. Mudrak, Austria

818. Shibao, Y., On the buckling of an elliptic plate with clamped edge, II, *J. phys. Soc. Japan* **12,** 5, 529–532, May 1957.

Author gives numerical solutions for problem discussed in part I of his paper [AMR **10,** Rev. 2870]. Convergence is such that the infinite determinant for the buckling load can be replaced by third- and fourth-order determinants. The results agree closely with the energy solution by S. Woinovsky-Krieger, *J. appl. Mech.* **4,** p. 177, 1937.

B. E. Gatewood, USA

819. Koiter, W. T., Buckling and post-buckling behavior of a cylindrical panel under axial compression, *Nat. LuchtLab. Amsterdam Rap.* S. 476, 14 pp., 1956.

The postbuckling behavior of narrow cylindrical panels, such as occur in stiffened cylindrical shells, is investigated for one set of boundary conditions along the longitudinal edges. It appears that the initial postbuckling stage is stable only for very narrow panels. A program for further research is outlined with respect to other boundary conditions, to the more advanced postbuckling stage, and to an experimental verification. It is conjectured that the behavior of a narrow curved panel in the advanced postbuckling stage will approach the behavior of a flat panel of the same width.

Notably missing from the list of references is Levy, S., "Large deflection theory of curved sheet," *NACA TN* 944, 1944.

From author's summary by G. Gerard, USA

820. Anderson, M. S., and Updegraff, R. G., Some research results on sandwich structures, *NACA TN* 4009, 12 pp., June 1957.

The results of compressive-buckling tests of steel sandwich plates are given, and the significant parameters which affect the strength of the plates are discussed. The various types of sandwich construction are shown to be comparable on a weight-strength basis with conventional high-strength aluminum-alloy construction.

From authors' summary

821. Ceradini, G., Lateral buckling of arches with symmetrical cross section with respect to the normal to the curve of the axis (in Italian), *G. Gen. civ.* **95,** 4/5, 306–335, 1957.

Static conditions of neutral equilibrium are found for arches of any shape, loaded with any kind of forces, with regard to lateral buckling. The following restrictions are imposed: (a) small curvature; (b) generic cross section symmetrical with respect to normal of the curve; (c) loads in the plane of the arch. Internal energy and work done by external loads are computed and then conditions of neutral equilibrium are also found by energy method. These general equations are compared with known particular solutions and satisfactory agreement is found. Exact solution of system of equations is not always possible. Approximate solutions by means of series or Vianello's iteration method are recommended by author.

H. Fernandez Long, Argentina

822. Gerard, G., and Becker, H., Handbook of structural stability. I. Buckling of flat plates, *NACA TN* 3781, 58 pp. + 46 figs., July 1957.

This handbook is intended to cover area between textbook and structures manual. Main text discusses assumptions, limitations, and background of available literature; appendix specifically treats practical application of results, which are summarized in comprehensive series of charts and tables.

Since columns are well treated in several books, part I is concerned with buckling of flat plates. After brief discussion of mathematical methods of solution, sections follow on boundary conditions, inelastic buckling and cladding reduction factors. Plasticity reduction factors were chosen on basis of agreement with test data and presented in nondimensional charts utilizing three-parameter description of stress-strain curves.

Results are then discussed and summarized in the appendix for buckling of rectangular plates under compression, shear, bending and combined loads, effect of pressure on buckling of rectangular plates, buckling of rectangular plates with variable loading and thickness, and buckling of parallelogram and triangular plates.

Reviewer noted some printing errors in Fig. 2(a) and disagreement between values of η in last line of table 2 and in title of Fig. 10.

F. J. Plantema, Holland

Joints and Joining Methods

Book—823. Kuhn, W. E., edited by, Arcs in inert atmospheres and vacuum, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, viii + 188 pp. $7.50.

"Arcs in inert atmospheres and vacuum" is the eighth subject in the Electrochemical Society series of books. This one is concerned, primarily, with presenting the existing state of the technology in this field. There are fourteen papers grouped into four parts: an introduction, the fundamentals of arc melting, the design and operation of arc melting furnaces, and the chemical application of arc.

The rapidly increasing commercial importance of electric arcs in industry emphasizes the need for a survey of the techniques. In the part of this book on the fundamentals of arc melting, two papers present the voltage-current characteristics of arcs in the rare gases and in vacuum with and without consumable electrodes. One paper presents proof of the existence of an optimum rate for the magnetic stirring of molten titanium in order to obtain the most desirable metallurgical characteristics in the ingot. A fourth paper lists the controlling variables for the most efficient melting rate with consumable electrodes. This paper also contains three sets of curves for the standard free-energy-versus-temperature diagrams of metal nitrides, oxides, and sulfides. These curves present the most important information in the book for chemical applications.

The third part of the book presents design and operating data for specific applications. These include vacuum arc furnaces for the melting of refractory metals, for the remelting of superalloys and steels, and for the melting of titanium and zirconium according to German developments. A three-phase, consumable electrode furnace and an electrode control system are also described. These papers are a good survey of the technology in this field as it is available from publications.

The part of the book on chemical applications consists of four papers, on all of which Charles Sheer of the Vitro Corporation of America is a joint author. Over half of the material deals with the nature, properties, and characteristics of high intensity arcs with some comparisons with low intensity arcs. These considerations show the regions of high temperature, direction of radiation, and conditions in the arc flame. Specific applications, as contrasted to fields of application, are not mentioned, probably for proprietary reasons. Four fields of application are listed in one article, and these are vaporization of refractory materials, distillation of refractory materials, decomposition of stable, complex oxides, and heating to promote vapor-phase reactions.

F. C. Todd, USA

Structures

(See also Revs. 772, 773, 774, 790, 796, 820, 821, 822, 859, 863, 903, 959, 1007, 1070)

824. Wei, B. C. F., Analysis of multiple-span continuous trusses, *Proc. Amer. Soc. civ. Engrs.* **83,** ST 2 (*J. Struct. Div.*), Pap. 1187, 22 pp., Mar. 1957.

Paper presents the method of the moment influence line as the basic tool in analyzing continuous trusses. This method, as compared to the conventional analysis of continuous trusses by the removal of reaction redundants, has the advantages that the computation for the stresses due to each unit loading is limited to two spans regardless of the number of spans in the truss, and that the constants for the solution of simultaneous equations are easily obtained by one simple operation. These advantages result in a saving of a considerable amount of time for the analysis of long-span continuous trusses of more than two spans, particularly those with unsymmetrical proportions. Computations for elastic weights and constants for the simultaneous equations are given in simple tabular form, suitable for use in actual design. A numerical example showing the complete analysis of moment influence lines for a four-span continuous truss is presented.

From author's summary

825. Barnett, R. L., Prestressed truss-beams, *Proc. Amer. Soc. civ. Engrs.* **83,** ST2 (*J. Struct. Div.*), Pap. 1191, 23 pp., Mar. 1957.

The purpose of this paper is to present a design procedure for simply supported beams which makes possible the utilization of statically indeterminate composite action and favorable initial stress distribution to strengthen available beam sections. A variation of the Queen Post truss with a pretensioned tie rod is studied, and weight savings of over thirty per cent are demonstrated by example designs. The techniques used are based entirely on elastic considerations.

From author's summary

826. Barta, J., Practical formulas for the stress analysis of the Langer girder (in French), *Acta Techn. Hung. Budapest* **16,** 3/4, 407–414, 1957.

For the static computation of the girder mentioned in title, formulas expressed in terms of a closed form are deduced. It is supposed that the arc is a parabola and is completely flexible; the suspending rods are infinitely approached (continuously placed). A table is provided to facilitate the use of the formulas.

From author's summary

Book—827. Theimer, O. F., Tables for design of wall-type girders in reinforced concrete (in German) [Hiistafeln zur Berechnung wandartiger Stahlbetonträgern] 4, 38 pp., 1956.

Basic analysis, developed and previously published by H. Bay, F. Dischinger, Craemer, R. Bortsch, K. Girkmann, A. Pucher, and author, is thoroughly discussed, and the results presented in charts and tables which considerably simplify relatively complicated calculations. Their usefulness is demonstrated in three examples.

J. J. Polivka, USA

828. Ekberg, C. E., Jr., Walther, R. E., and Slutter, R. G., Fatigue resistance of prestressed concrete beams in bending, *Proc. Amer. Soc. civ. Engrs.* **83,** ST4 (*J. Struct. Div.*), Pap. 1304, 18 pp., July 1957.

Paper discusses a method for predicting fatigue strength of bonded prestressed-concrete beams under pure bending. Writer notes that in the small number of fatigue tests conducted on prestressed concrete by other investigators there was wide disagreement on the dynamic safety factor. This is not surprising in view of the statistical nature of fatigue, its localized nature, and of the complexities of a composite engineering material under fatigue loading. Author states that his method has been used with success on several investigations. He concludes that: (1) The dynamic ultimate moment is always less than the static ultimate moment but it varies widely; (2) the dynamic cracking moment is always smaller than the static cracking moment; (3) the ratio of the dynamic ultimate moment to the static ultimate moment is increased either by raising the level of prestrain or increasing the percentage of steel in the beam.

H. Majors, Jr., USA

829. Balazs, G., and Kilian, J., Creep and compaction of high-strength concrete and concrete with small amount of creep (in Hungarian), *Mélyépitéstudományi Szemle* **7,** 1/3, 52–64. 1957.

Authors tell of the strain tests carried out on high-strength concrete in the laboratory of the Chair No. 2 for Bridge-Construction of the Technical University of Building, Civil and Transport Engineering in Budapest. These tests show a final value of the creep coefficient $m = 2.5$ for the concrete "B 500" (i.e., with a minimum compressive strength $k = 500$ kg/cm^2 at 28 days' age). After having dealt with the rules regarding the passing of creep in time [Saliger, Aratinian, Leonhardt], authors compare the test results with the values given by formulas and with the tests of Roš, and come to the conclusion that Leonhardt's formulas give good approximate values.

Under the influence of sustained load there arises a compaction in the compressed structure. Due to the compaction, the strength and the Young's modulus of the concrete increase. The compaction is the greater the earlier the concrete is loaded.

The purpose of another group of tests was to ascertain the influence of different methods of water-content reduction on shrinkage and creep of concrete. These tests have shown that shrinkage and creep decrease to great extent by using a hardening technology based on combination of vapor treatment and dry-heat treatment. Such a combined technology is more economical than the vapor treatment and not so dangereous as the dry-heat treatment as regards the final strength of the concrete.

I. Koranyi, Hungary

830. Morice, P. B., The analysis of prestressed concrete structures and the application of recent research, *Proc. Instn. civ. Engrs.* **6,** 445–492, Nov. 1956.

Paper is a general report on the recent research of the Cement and Concrete Association on the behavior of prestressed-concrete structures. In the first few paragraphs, author derives a set of expressions for the analysis of prestressed members in both statically determined and indeterminate structures. While this part of the report is rather condensed and simplified, a great wealth of information is presented in the second part concerning experimental results of continuous beams, portal frames, slab bridge decks, and of the transmission lengths in factory-made pretensioned units.

Attention should be paid to the extensive and interesting discussion following the paper, title source, pp. 477–492.

F. M. Mueller, USA

831. Swida, W., The problem of creep in slabs and disks subjected to prestressing in two directions (in German), *Publ. int. Assn. Bridge struct. Engng.* **16,** 469–484, 1956.

Paper deals with creep effects in plates and slabs prestressed in two directions. A system of two simultaneous first-order differential equations is derived and solved for the loss of tensile force in the cables. In the case of an eccentrically prestressed plate, the deflections are also determined.

A. Phillips, USA

832. Albone, T., and Manning, H. E., A post stressed concrete gasholder tank at York, *Struct. Engr.* **35,** 7, 252–254, July 1957.

833. Marshall, W. T., Plastic design in reinforced concrete, *Struct. Engr.* **35,** 7, 243-251, July 1957.

834. The terminology of prestressed concrete (Part I), *Concr. constr. Engng.* **52,** 5, 159-160, May 1957.

835. The terminology of prestressed concrete (Part II), *Concr. constr. Engng.* **52,** 6, p. 210, June 1957.

836. Fountain, R. S., and Viest, I. M., Selection of the cross section for a composite T-beam, *Proc. Amer. Soc. civ. Engrs.* **83,** ST4 (*J. Struct. Div.*), Pap. 1313, 30 pp., July 1957.

Derivation of exact formulas for the properties of composite T-beams (concrete and steel) and approximate equations are presented. Two detailed designs of bridge beams demonstrate authors' assertion that the paper enables one to select rapidly the steel section for a composite structure. Graphs portray how to eliminate the usual tedious calculations and to employ approximate methods for the selection of trial members. Methods apply either to composite beams made with symmetrical rolled steel sections or to rolled steel sections having tension cover plates or with built-up steel sections. Authors assume that there is no slip between slab and steel beam; that there is a linear stress distribution when deriving exact formulas for section properties.

H. Majors, Jr., USA

837. Bodin, H., Wood diaphragms: Progress report of a subcommittee of the Committee on Timber Structures of the Structural Division, *Proc. Amer. Soc. civ. Engrs.* **83,** ST4 (*J. Struct. Div.*), Pap. 1143, 10 pp., Nov. 1957.

Paper is an advance presentation of a chapter of the contemplated new edition of ASCE Manual of Engineering Practice No. 17 on "Timber piles and construction timbers." The scope of the paper is limited to a general discussion and definition of wood diaphragms, their functions and purposes. Design provisions are given consideration. A 33-item bibliography refers to technical data which were available to the committee.

In light of the relatively recent introduction of the diaphragm concept in building construction, laboratory test data and field experience are limited. "Present knowledge is distinctly incomplete and certain types are practically nonexistent."

While it is stated that "the effectiveness of a diaphragm is dependent on the adequacy of (its) attachment....," only a small amount of the research efforts involved concerned itself with the fastening of the structural elements and their attachment to adjacent elements. Recently initiated studies of improved fastening procedures for wood diaphragm components in the Wood Research Laboratory of Virginia Polytechnic Institute are expected to throw more light on this subject.

E. G. Stern, USA

838. Croftan, F. G., Nailed fir plywood gussets for sawn lumber three-hinge arches, *Forest Prod. J.* **7,** 9, 295-298, Sept. 1957.

Tests were performed on three-hinged sawn-lumber arches of 9 to 19-ft span. Nailed plywood tension gusset plates provided firm joints at the haunches to transmit the existing bending moments. The test loads were applied by means of water run into calibrated plywood tanks hanging on cables from the arches.

The lumber arches were found to be satisfactory, practical, and competitive in cost with other types of framing.

E. G. Stern, USA

839. Silverman, I. K., The lateral rigidity of suspension bridges, *Proc. Amer. Soc. civ. Engrs.* **83,** EM3 (*J. Engng. Mech. Div.*), Pap. 1292, 18 pp., July 1957.

Paper is concerned with the behavior of suspension bridges under the action of uniformly distributed wind loads. The differential equation deduced has no known exact solution in closed form, and author undertakes to establish a solution in terms of a Fourier series by means of the principle of virtual work. The coefficients of the Fourier series are determined from a set of simultaneous equations as usual, and it is shown that they depend on three dimensionless parameters which are further defined. An example is shown and curves are drawn for deflection and bending moment of the wind truss. A discussion of the importance of the parameters is presented. Finally, the oscillation of the bridge is briefly treated and the natural frequency of the bridge is found. Paper is so compressed that the details of the deduction of the differential equations are left out, which complicates a check of the assumptions that have been made.

L. N. Persen, Norway

840. L'Hermitte, P., Contribution to the study of the stability of offshore protecting structures, *Rev. gén. Hyd.* no. 76, 26-33, Jan.-Feb. 1957.

The works for protection against the action of the sea such as piers and breakwaters should be capable of resisting the objectionable action of heavy storms so as to protect harbor equipments to a sufficient extent, but such works are extremely expensive and it is necessary to define with a maximum accuracy the criteria to be adopted when defining its characteristic features.

The knowledge of the risks which may appear in the working of a harbor as a consequence of the risk of destruction of the protecting works is essential.

Said risks may be defined by incorporating the probability notion of wrecking of works at sea, which probability is obviously calculated starting from the probability of the presence of swells in the area considered. It is, however, possible to define in an accurate manner the probability of wrecking of works at sea as a function of the probability of occurrence of swells only by incorporating as a further notion the periodicity of the maintenance of the work.

The probabilities of wrecking consequent on the amplitude of the swells to be considered may form an important element to be considered in the selection of the protecting means for a harbor system and they may furthermore supply accurate data for the correct interpretation of results of tests made in a small-scale model.

From author's summary

841. Ross, E. W., Jr., Effect of boundary conditions in limit analysis of plastic structures, *J. appl. Mech.* **24,** 2, 314-315, June 1957.

The limit-analysis notions for an elastic-plastic body are applied to yield several general results about the effect on the collapse load of changes in body shape and loading conditions.

From author's summary

842. Johnson, C. L., and Cleveland, F. A., Design of air frames for nuclear power, *Aero. Engng. Rev.* **16,** 6, 48-57, June 1957.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 762, 790, 803, 814, 829, 831, 833, 841, 861, 862, 870, 872)

843. Gerstle, K. H., Deflections of structures in the inelastic range, *Proc. Amer. Soc. civ. Engrs.* **83,** EM 3 (*J. Engng. Mech. Div.*), Pap. 1290, 22 pp., July 1957.

Angle changes and deflections of rectangular beams are computed under assumption of an ideally-plastic material. Stages from first yield up to full plastification are included, and applications to compatibility conditions of indeterminate systems are discussed. Similar information has been given in reviewer's earlier papers [*Ing.- Arch.* **13,** 285-292, 1943 and others].

H. Craemer, Germany

844. Sokolovskii, V. V., Equations for plastic flow in the boundary layer (in Russian), *Prikl. Mat. Mekh.* **20,** 3, 328–334, May-June 1956.

Solution of Saint-Venant's equations for stress components in plane plastic flow in neighborhood of curved rigid boundary ($y = 0$), where x and y are orthogonal coordinates in tangential and normal direction of boundary curve, is approximated by $\sigma_x = 2k[s(x)+S-\Phi]$ $\sigma_y = 2k[s(x)+S+\Phi]$, $\tau_{xy} = k[1-2\Phi^{-2}]$. Here $2k$ is yield stress in tension and $s(x)$ normal stress at boundary $y = 0$. Functions S and Φ are assumed to be small quantities. Also, velocity components are represented by $u = u(x) + U$, $v = v(x) + V$, where $u(x)$, $v(x)$ are velocity components at boundary and U, V small quantities, vanishing for $y = 0$. From linearized Saint-Venant's equations and boundary conditions at $y = 0$, all quantities S, Φ, U, and V may be determined by integration in finite form. For small distances y from rigid boundary, quantities S, Φ, and U are proportional to $y^{1/2}$ and V to y. Well-known cases of plastic flow with rotational symmetry outside rigid circle and extrusion of plastic material between parallel rough rigid plane walls enter as special cases. F. K. G. Odqvist, Sweden

845. Ivlev, D. D., Use of linear tensor relations in plasticity theory (in Russian), *Prikl. Mat. Mekh.* **20,** 2, 289–292, Mar.-Apr. 1956.

In elaborating the linear theories of plastic flow, attention is given to systems in which displacements, stresses, etc., can be resolved into mutually independent contributions. Considering the distortion of thin tubes by extension and bending, relations are obtained which are accessible to experimental tests.

R. Eisenschitz, England

846. Zhudin, N. D., Work of steel non-slotted girders in the elastic-plastic stage in the case of repeated variable and mobile loads (in Russian), *Sb. tr. in-ta stroit- mekhan. Akad. Nauk Ukr. SSR* no. 19, 5–13, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5415.

Results are given of tests on models of two-arch non-slotted girders with repeated variable loading, and also under the action of a mobile and repeatedly variable load in the case of yielding of the mean support. The tests were performed with girders of 20 × 30 mm rectangular and 30 × 40 mm H section on a special machine prepared in the Institute of Building Mechanics of the Academy of Sciences of the Ukrainian SSR. The total length of the girder was 1000 mm.

As a criterion of the efficiency of the girder, author took the cessation of increase of the deformation after multiple application of the load.

It was shown that the limiting state of the girders in all cases is determined by the value of the limiting load, which is not less than for its single application in a dangerous section.

In the case of repeated variable loading, the actual limiting load was found to be above the limiting load calculated according to the Bleich theory [Bleich H., *Bauingenieur* 1932, 19/20] by approximately 15%. A. I. Strel'bitskaya, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

847. Gutkin, A. M., Motion of a viscous-plastic medium in a gap between two rotating cones (in Russian), *Kolloid Zh.* **17,** 6, 421–423, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5386.

Solution of the problem of motion of a viscous-plastic medium in a gap between two rotating co-axial cones having a common apex.

By integration of the state equations of the viscous-plastic medium in spherical coordinates an expression was obtained for the case when the displacement covers the whole region between the cones:

$$\omega = \left(\frac{3M}{2\pi R^3\mu} - \frac{2\tau_0}{\mu}\right) \int_\alpha^\beta \frac{d\theta}{\sin^3\theta} + \frac{\tau_0}{\mu}\left(\frac{\cos\alpha}{\sin^2\alpha} - \frac{\cos\beta}{\sin^2\beta}\right)$$

where ω is the angular velocity of the rotating cone, M is the rotational moment, R is the portion of the gap filled according to the generatrix of the cone, τ_0 is the limiting stress of the displacement, μ is the plastic viscosity, and 2α and 2β are the cone angles.

A similar equation was obtained for the case when the displacement does not cover the whole region between the cones, i.e., there is a zone of elastic deformation where the stress is less than τ_0.

In solving the problem it was assumed that the boundary of the viscous-plastic medium filling the space between the cones is a spherical surface. N. I. Malinin, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

848. Gill, S. S., Three "neutral" loading tests, *J. appl. Mech.* **23,** 4, 497–502, Dec. 1956.

Experiments on "neutral" loading tests were carried out to compare the Von Mises-Hencky and Guest yield criteria for the material of alpha brass. Three tests were conducted using hollow tubes subjected to combined torsion and internal pressure, two tests on constant octahedral shear stress, and one test on constant maximum shear stress. Results indicate that the constant octahedral shear stress tests give small plastic strain which suggests that the yield surface is elongated slightly in the direction of the initial shear stress. The constant maximum shear stress test gives larger plastic strains. It is concluded that much smaller increments of stress will be required with, consequently, the requirement of greater sensitivity of the equipments to investigate the loading surface. C. T. Yang, USA

849. Segawa, W., Stress-strain relations for viscoelastic large deformation, *J. phys. Soc. Japan* **12,** 9, 996–998, Sept. 1957.

Stress-strain relations for Maxwell and Voigt viscoelastic elements are modified for large deformations. Resulting equations are applied to three cases of simple extension: constant stress, constant strain, constant rate of strain. I. M. Krieger, USA

Failure, Mechanics of Solid State

(See also Revs. 828, 868, 869, 873)

Book—850. Elcock, E. W., Order-disorder phenomena, New York, John Wiley & Sons, Inc., 1956, ix + 166 pp. $2.50.

The interest of physicists and metallurgists in order-disorder transformations in metallic alloys does not seem to weaken, perhaps even is gaining in intensity, as evidenced by a great number of papers on this topic appearing every year in the technical literature. The problem is a difficult one. Despite the great wealth of experimental data amassed, a satisfactory theory capable of quantitative predictions is still to come.

Dr. Elcock's short treatise on this subject is welcome, inasmuch as it auguments the few review articles available in this field. The author, probably because of space limitations, has confined himself chiefly to a discussion of the theoretical aspect of the problem, in particular to an exploration of the Ising model for ordering. Onsager's exact solution for the two-dimensional case is discussed only briefly. This approach is to be recommended, inasmuch as the book is intended for an audience not necessarily well acquainted with the powerful mathematical tools employed by Onsager. Moreover, the latter model cannot be applied even qualitatively to actual three-dimensional cases. The Ising model is treated by Dr. Elcock with exceptional clarity and a great regard for the difficulties which the reader may encounter. When he compares the theory with experimental data, he emphasizes the importance of distinguishing the properties of a model from those of the mathematical approximations.

The book consists of five short chapters, covering such topics as binary alloy ordering, the specification and determination of the state of order in a binary alloy, approximate theoretical treatments of binary alloy ordering, order-disorder effects in nonstoichiometric alloys, and the relation of binary alloy ordering to other topics in solid-state physics. In the second chapter there is an adequate exposition of the methods by which order parameters are obtained from x-ray data. Unfortunately, the description of the recent results in this field is extremely brief. This is also true of the treatment of many interesting experimental results, such as the effect of order upon the mechanical and magnetic properties of alloys. In the first chapter these are only very briefly discussed, if mentioned at all. The remaining three chapters very ably present the approximate treatments of the Ising model, ordering in nonstoichiometric alloys, and the relation of order-disorder to magnetic theory. The latter topic, again, suffers greatly from brevity, apparently enforced upon the author by rigid editorial requirements.

The most unfortunate aspect of the book is its almost total lack of pertinent references. They are only given when illustrations are reproduced from original work. A short bibliography of selected articles and chapters from books is included, but it is obviously inadequate and cannot make up for the running references in the text.

The book is an excellent introduction to the subject for experimenters who may find it helpful in planning their research and rationalizing their results. It will also be read with profit by a large audience of physicists, chemists, and material engineers.

G. C. Kuczynski, USA

Book—851. Robertson, W. D., edited by, Stress corrosion cracking and embrittlement, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, viii + 202 pp. $7.50.

"Stress corrosion cracking and embrittlement" is the seventh subject in the Electrochemical Society series of books. This one is particularly timely for clarification of the status of this relatively ill-defined subject. It delineates the range of phenomena that are included in this field and presents the status of present concepts on these phenomena. The publication contains fourteen papers from a Symposium on stress corrosion cracking which was held at Boston in October, 1954. The papers are relatively well edited for their technical content. It is also refreshing and not too common to observe an editor who does not hesitate to insert notes in the papers which present his ideas of the correlation of parts of the papers with the general concepts on the subject.

The arrangement and extent of the included subject matter is excellent. The first article presents an over-all survey of stress corrosion cracking, the mechanism and the unanticipated high rate of crack propagation. The next article presents the necessary background from solid-state physics on stress risers and dislocations. The next two articles apply the general considerations to homogeneous alloys. The remainder of the papers generally deal with specific applications, such as stainless steels in air and in aqueous chloride solutions, mild steels, mechanism of chemical cracking and the effect of hydrogen in steel alloys. The final paper is concerned with laboratory techniques.

This book defines the field, presents the basic theory, and summarizes the experimental work in this relatively new field. It provides background information which is useful in classifying failures.

F. C. Todd, USA

852. Zaid, M., and Paul, B., Mechanics of high speed projectile perforation, *J. Franklin Inst.* **264,** 2, 117-126, Aug. 1957.

The problem of perforation of thin plates by high-speed projectiles is considered from a momentum viewpoint. Equations representing the magnitude and direction of forces, velocity, etc., as a function of penetration distance are derived for the conical projectile under normal impact. Good correlation between the theory and experiment is obtained.

From authors' summary by J. S. Rinehart, USA

853. Levy, J. C., Cumulative damage in fatigue—a design method based on the S-N curve, *J. roy. aero. Soc.* **61,** 559, 485-491, July 1957.

Fatigue is considered with two stress levels applied alternately. Method is outlined for finding safe value of N from standard S-N curves. Results are checked against comprehensive experimental results. Three stress-level conditions are discussed.

R. N. Arnold, Scotland

854. Schijve, J., Fatigue crack propagation in light alloys, *Nat. LuchtLab. Amsterdam Rap.* M. 2010, 25 pp. + 2 apps, + 8 tables + 13 figs., 1956.

This booklet is on research supported by Netherland Aircraft Development Board, and it gives theoretical concepts of the fail-safe principle for the fatigue cracks in aircraft structures. After summarizing approximately seventy papers including author's, a general review of fatigue phenomenon is given, the significance of fatigue crack propagation on general fatigue problems is discussed, and then the consequences of fatigue cracks in aircraft structures are considered.

Attention should be paid to following items when the fail-safe principle is applied. (1) To judge the fail-safety of a structure, the critical parts, i. e. those parts which may be liable to fatigue, must be known. (2) Once a fatigue crack has started it should not grow rapidly. (3) A fatigue crack should not have a severe notching effect for high static loads. (4) To assure points (2) and (3) it is necessary to have at least a qualitative idea about the crack-stopping characteristics of the neighboring elements of the critical parts which eventually will have to retard the growth of the fatigue crack. (5) An inspection schedule must be based on a fatigue analysis of the structure. Sufficient accessibility for inspection of the critical parts must be provided.

Paper includes eight useful numerical tables and thirteen figures which are cited from various papers on fatigue-crack propagation.

H. Mii, Japan

855. Pironneau, Y., Contribution to the study of the deformation of metals under repeated impacts (in French), *ONERA Publ.* no. 75, 84 pp., 1955.

Paper presents a study of impact fatigue, or the behavior of metals under repeated impacts which are insufficient to cause rupture; also, author endeavors to find a method of predetermining failure under such conditions. Comparisons are made between the cumulative energy of impacts and energy of common tensile tests to produce a specific deformation.

Several types of test equipment are described. Principal one consists of a carrier on rails which is accelerated to some velocity, usually limited to 56 fps. One end of specimen is attached to carrier, the other end is loaded with a mass. When carrier is stopped short by a steel beam, the kinetic energy of the loaded mass produces tensile elongation of specimen. Successive impacts (5 to 15) are imposed on unnotched specimen.

For annealed aluminum, elongation depends only on the cumulative energy of impacts. Energy absorbed is the same as in common tensile tests. For work-hardened aluminum, the elongation for first impact is low. This impact appeared to reduce hardening so that for subsequent impacts behavior is the same as for annealed. For soft steel, the energy of elastic deformation becomes appreciable and must be substracted from the energy of each impact. For hardened steel, the elastic component becomes much greater relatively. There appears to be some hardness reduction after the first impact.

Author concludes that impact damage, as indicated by elongation, suffered from each stroke is proportional to the impact energy in excess of elastic energy of specimen and that this damage is cumulative. There were no indications of brittle fracture under these limited impacts, but elongation at rupture was for all materials in excess of that obtained in common tensile tests.

Photomicrographs indicate that failure occurs in glide planes. The structure after impact failure differs in some ways from that of tensile failure.

Theories upon which this study is based are covered by references, largely U.S. and British.

E. B. Shand, USA

856. Schijve, J., and Jacobs, F. A., Research on cumulative damage in fatigue of riveted aluminum alloy joints, *Nat. LuchtLab. Amsterdam Rap.* M. 1999, 53 pp., Jan. 1956.

Two-step tests and interval tests were performed on 24 S-T Alclad riveted lap joints to study the cumulation of fatigue damage in this type of joint and to verify the linear cumulative damage rule.

Available data on light alloy specimens are reviewed and compared with the results of the present investigation. Author tries to establish some general trends of the cumulative damage phemomenon. Some proposed cumulative damage rules are discussed with respect to the experimental results and general accepted features of the fatigue phenomenon. Some remarks are made on the life estimation of structures under service loading. Proposals for further investigation are made.

From authors' summary

857. Frost, N. E., Non-propagating cracks in vee-notched specimens subject to fatigue loading, *Aero. Quart.* **8,** 1, 1–20, Feb. 1957.

Reversed direct stress and rotating bending fatigue tests have been carried out on vee-notched specimens of aluminum alloy, nickel-chromium steel, and mild steel.

Diagrams are presented showing the relationship between the geometric stress concentration factor K_t and the strength reduction factor K_f. It was found that nonpropagating cracks formed in the roots of the sharper notches. These cracks formed at or above some critical value of K_t, the value depending on the specimen material. Below the critical value of K_t, cracks did not form unless the applied nominal stress exceeded that at the fatigue limit, and a crack, once formed, continued to propagate until the specimen failed. Above the critical value of K_t, nonpropagating cracks formed at nominal stresses less than the fatigue limit, the stress having to be increased to the latter value in order to propagate the crack. This critical value of K_t coincided with the maximum K_f value realized. It would appear that K_f equals K_t up to a certain value of K_t; there is then a transition where K_f reaches a maximum at the critical value of K_t. Increasing the value of K_t above the critical value causes no further increase and may tend to decrease the value of K_f.

The conclusions drawn apply only when the fatigue stresses are completely reversed, i.e., the mean load is zero.

From author's summary

858. Wiene, P. E., Full-scale fatigue tests of diesel engine elements, *Inst. mar. Engrs. Trans.* **68,** 3, 39–46, Mar. 1956.

Paper deals with a series of experiments undertaken by Burmeister and Wain and by various Danish testing laboratories on their behalf.

In the opening paragraphs a comparison is made between laboratory tests and service experience; experiments are mentioned with small rotary bend tests, with nitriding which seems to be able to treble the fatigue strength of a notched bar, with cast iron, as well as a series of experiments which indicated that the fatigue strength does not continue to fall when a notch is made sharper.

In addition, the paper deals with experiments with springs, the fatigue strength of which has been greatly increased by shot peening, and also experiments with the fashioning of crank throws and with piston rods, the strength of which was more than doubled by a series of alterations in design, material, machining and tightening. The paper also refers to experiments with piston rods shrunk into the crossheads by oil pressure. Finally, fatigue tests with a large welded construction, loaded in bending and tested as welded and after annealing, are dealt with.

From author's summary

859. Heywood, R. B., Correlated fatigue data for aircraft structural joints, *Aero. Res. Counc. Lond. curr. Pap.* 227, 9 pp. + 7 figs., June 1955.

Results of fatigue tests carried out at R.A.E. on typical aircraft wing structural joints are correlated to give an indication of general fatigue behavior. The results are plotted in the form of S-Log N curves, and these indicate that the mode of behavior cannot be attributed to any single factor, such as the type of aluminum alloy, the ultimate tensile strength, or the mean stress of the fatigue cycle. The detailed method of design undoubtedly has a predominant influence on behavior, but this quality is not revealed by a broad classification according to the proportion of load transmitted at holes.

From author's summary

860. Hartman, A., The safety of transport aircraft in respect of fatigue loads, *Nat. LuchtLab. Amsterdam Rap.* NLL-TM 2008, 51 pp., 10 figs., 1956.

Report gives a survey of the methods published in the literature to determine and calculate the safety of transport aircraft in respect to fatigue loads anticipated in service.

From author's summary

Material Test Techniques

(See Rev. 884)

Mechanical Properties of Specific Materials

(See also Revs. 820, 823, 837, 838, 848, 854, 856, 871, 882, 883, 884, 885, 1008)

Book—861. Kinney, G. F., Engineering properties and applications of plastics, New York, John Wiley & Sons, Inc., 1957, vii + 278 pp. $6.75.

Following a brief introduction into the general nature of plastics, the principal classes are discussed in individual chapters. This, the major part of the book, includes all of the important thermoplastic and thermosetting resins plus rubber. Chemistry, properties, and principal uses are covered.

The second portion of the book briefly discusses molding methods and then devotes individual chapters to engineering properties, particularly behavior under stress; thermal properties, optical properties, and electrical properties. Following this is a final chapter on the chemistry of plastics.

This book is intended for the engineer who is not familiar with plastics. It gives him a good introduction and provides the necessary groundwork for more specialized work in particular phases of the subject.

A. G. H. Dietz, USA

862. Nandeeswaraiya, N. S., The elastic and plastic properties of gasket materials, *J. Instn. Engrs. India,* **37,** 6 (part 2), 621–644, Feb. 1957.

Study of the elastic and plastic properties of gasket materials, commonly used for low-pressure sealing operations, is approached from designers' point of view. Physical tests to yield reproducible data, necessary for the mathematical treatment of the gasketed

joints in service, have been evolved and test procedure standardized to insure reliability and consistency. Equations defining stress-strain relations for the gasket materials tested have been obtained from the experimental data. Application of the results thus obtained in the rational design of the gasketed joints is briefly indicated. From author's summary

863. Youngs, R. L., Bolt-bearing properties of glass-fabric-base plastic laminates, *For. Prod. Lab. Rep. U. S. Dept. Agric.* no. 1824-C, 11 pp. + tables + figs., Feb. 1957.

Report presents the results of bolt-bearing tests of two parallel-laminated glass-fabric-base epoxy laminates. The data supplement those of *For. Prod. Lab. Rep.* nos. 1824, 1824-A, and 1824-B, in which results of bolt-bearing tests of several polyester laminates were presented

The laminates were either 1/4 inch or 1/8 inch thick. They were tested both dry and wet, at angles of 0°, 90°, and 45° to the warp direction, and at D/t ratios of 1 and 4. Included are data on the bolt-bearing properties of the materials and on the effects of edge and side distance.

The epoxy laminates tested in this work were stronger in bolt-bearing than comparable polyester laminates. The average values of maximum bearing stress were all higher than corresponding values for comparable polyester laminates by about the same proportion as tensile strength. Wet conditioning had relatively little effect on bolt-bearing properties. An edge distance of 4.5 D and a side distance of 3.0 D were large enough to prevent failure other than by crushing under the bolt.

From author's summary

864. Symposium on high polymers; under auspices of the National Chemical Laboratory and the Plastics Research Committee, Poona, India, Mar. 1957, 9 papers.

865. Decker, R. F., Rowe, J. P., and Freeman, J. W., Influence of crucible materials on high-temperature properties of vacuum-melted nickel-chromium-cobalt alloy, *NACA TN* 4049, 34 pp., June 1957.

A study of the effect of induction-vacuum-melting practice on the high-temperature properties of 55Ni-20Cr-15Co-4Mo-3Ti-3Al alloy revealed that a major variable was the type of ceramic used as a crucible. Reactions between the melt and magnesia or zirconia crucibles apparently increased high-temperature properties at 1600 F by introducing small amounts of boron or zirconium into the melts.

Heats melted in alumina crucibles had relatively low rupture life and ductility at 1600 F and were prone to crack during hot-working. Apparently this resulted from lack of derivation of boron or zirconium from the crucible.

When melting was carried out in zirconia crucibles with a variety of melting practices, increases in rupture life and ductility and reduction of cracking during hot-working correlated with increases in zirconium content derived from the crucibles. However, the best heats made in zirconia crucibles had properties below those considered characteristic of the alloy.

Melting in magnesia led to heats with rupture properties and resistance to cracking during hot-working which were improved over those of the heats made in alumina. The rupture life was increased to the range considered characteristic of the alloy. This appears to be related to boron content resulting from crucible reaction.

Controlled additions of boron and zirconium made to heats melted in alumina crucibles gave heats with properties which correlated with the earlier results from heats where zirconium was derived from zirconia and boron from magnesia. This supports the postulation that the introduction of these elements though melt reaction with the crucibles was responsible for the improved properties. From authors' summary

866. Grala, E. M., Investigation of the NiAl phase of nickel-aluminum alloys, *NACA TN 3828,* 33 pp., Jan. 1957.

867. Seemann, H. J., and Staats, H., Vibration treatment of metals, *J. acoust. Soc. Amer.* **29,** 6, 698–701, June 1957.

The treatment of solid and liquid metals by elastic vibrations is discussed. Particular attention is paid to the electrodynamic method in which the alternating field of a coreless induction furnace has a strong static magnetic field superimposed on it, so that the molten metal under treatment, itself becomes the sonic transducer with the production of radially directed vibrations. An expression is derived for the acoustic efficiency of this arrangement. Various special designs are described.

From authors' summary

868. Ball, J. G., Metallurgical research in nuclear power production, *J. Inst. Metals* **84,** 239–250, 1955–1956.

The range of metals of special interest in nuclear energy is described, and an account is given of the features of reactors which influence metallurgical problems. These problems are discussed under the headings: (1) irradiation stability, (2) thermal stability, (3) sheathing materials, (4) corrosion, (5) fabrication, and (6) alloying and physical properties.

From author's summary

869. Hagel, W. C., and Becht, E. F., Structural stability of modified 12-chromium alloys, *Trans. ASME* **78,** 7, 1439–1446, Oct. 1956.

In addition to possessing an attractive combination of mechanical properties for turbine applications, certain modified 12-chromium alloys were found to be structurally stable after long-time static aging and service exposure at high temperatures. However, two precipitation reactions have been observed to occur unpredictably in 12 Cr-Co-W-V alloy. The precipitating phases have been identified, and their effects upon mechanical properties are reported. After about 200 hr at 800 to 950 F (445 to 510 C), precipitation of chromium-rich ferrite causes decreased impact resistance and increased hardness; after about 6000 hr under stress at 950 to 1200 F (510 to 650 C), sigma formation causes an extreme decrease in impact resistance and no significant increase in hardness. From authors' summary

870. Turner, F. H., and Blomquist, K. E., A study of the applicability of Rabotnov's creep parameter for aluminum alloy, *J. aero. Sci.* **23,** 12, 1121–1122 (Readers' Forum), Dec. 1956.

871. Baldwin, E. E., Effect of neutron irradiation on the mechanical properties of some structural steels, *Welding J.* **36,** 7, 342s–347s, July 1957.

Tensile and impact specimens of ASTM A302B steel were irradiated at 500 and 700 F to integrated fast fluxes of $3.8 + 10^{18}$ nvt. Notched-bend specimens of ASTM A201 steel were irradiated at 300–400 F to integrated fast fluxes of 4.3×10^{20}. Results indicated little or no change in properties of the A302, but substantial increases in strength and loss of ductility and energy absorption ability of the A201. Substantial recovery of the A201 damage could be accomplished by annealing at 600 F.

From author's summary

872. Glen, J., Effect of alloying elements on the high-temperature tensile strength of normalized low-carbon steel, *J. Iron Steel Inst. Lond.* **186,** 1, 21–48, May 1957.

The object of the investigation was to study the effect of individual alloying elements on the high-temperature tensile strength of normalized low-carbon steel. For this purpose a series of steels containing varying amounts of alloying elements was prepared. Some of these steels were made both with and without the addition of aluminum. The elements investigated were manganese,

chromium, molybdenum, tungsten, vanadium, titanium, silicon, nickel, and copper. It was found that for a simple iron-carbon alloy one strain-age-hardening effect was obtained with a maximum at about 200C. With a little nitrogen present, this strain-age-hardening effect was intensified. With the addition of either manganese, chromium, molybdenum, tungsten, or copper, an additional strain-age-hardening effect was obtained at a temperature higher than 200C, the actual temperature depending on the element used. A strain-age-hardening effect due to vanadium or titanium was not obtained with the experimental conditions used. It was also found that the alloying elements modified the strain-age-hardening due to carbon and nitrogen.

Corresponding to each strain-age-hardening effect at a certain temperature, a minimum in reduction of area was also obtained. It was concluded that the maxima in stress and the minima in ductility were related to some form of coherent precipitation of carbides or alloy carbides in the dislocations.

From author's summary

873. Rosenberg, S. J., Temper brittleness of boron-treated steels, *J. Res. nat. Bur. Stands.* **58,** 4, 175-187, Apr. 1957.

Two series of steels, melted to the base composition of 8140, were studied to ascertain whether titanium and zirconium (present in many commercial boron addition agents) had any adverse effect upon the impact properties of the base steels, particularly with reference to temper brittleness.

The results obtained indicate that with fully hardened steels tempered at 1200F, the presence of relatively small amounts of titanium as introduced into the test steels by the boron addition agents is sufficient to cause an impairment in the Charpy V-notch impact properties of the steels or an increased susceptibility to temper brittleness, or both. This was confirmed by the addition of titanium without boron. Similar effects, previously thought possibly due to the presence of zirconium, were not observed.

From author's summary

874. Pallister, P. R., Specific heat and resistivity of mild steel, *J. Iron Steel Inst. Lond.* **185,** 4, 474-482, Apr. 1957.

The "spot" method has been used for the measurements of the specific heat of mild steel from room temperature up to 1000C in such a way as to approach equilibrium conditions. The investigation involved thermal analysis at various rates of heating and cooling and also observations on electrical resistivity over the same range of temperature. From author's summary

875. Nippes, E. F., Savage, W. R., Grotke, G., and Robelotto, S. M., Studies of upset variables in the flash welding of steels, *Welding J.* **36,** 4, 192s-216s, Apr. 1957.

876. Gratzl, A., and Wallpach, G., On the actual moduli of elasticity of beech plywood in compression (in German), *Holzforschung und Holzverwertung* **9,** 4, 57-59, Aug. 1957.

Comparative tests were performed on solid and laminated beech as well as beech plywood, with the load applied parallel to the grain and perpendicular to the grain in both the tangential and radial directions. The laminations consisted of sawn and peeled veneers.

The tabulated test results indicate that the modulus of elasticity of the test sample is influenced to a considerable degree by the grain direction as well as by the method of veneer manufacture, whether sawn or peeled. E. G. Stern, USA

877. Kelsey, K. E., and Kingston, R. S. T., The effect of specimen shape on the shrinkage of wood, *Forest Prod. J.* **7,** 7, 234-235, July 1957.

On the basis of tests on 787 wood specimens from 137 trees, of 32 wood species, it is suggested that shrinkage in the tangential, radial, and longitudinal directions is determined on a single 1 × 1 × 4-in. specimen, with the 4-in. direction parallel to the grain and the other dimensions in the tangential and radial directions. This procedure would eliminate the use of three separate test specimens and tests, and decrease material requirements and work involved. E. G. Stern, USA

Plasticity, Forming and Cutting

(See also Rev. 865)

Book—878. Town, H. C., and Colebourne, R., Engineering inspection, measurement and testing, New York, Philosophical Library, Inc., 1956, 192 pp.

879. Kubota, M., Kotorii, T., and Kanai, M., Study on shave-turning, *J. mech. Lab. Tokyo* **3,** 1, 24-32, 1957.

In this brief paper authors report on "shave-turning," use of a "new" type of tool having a straight edge, tangential to the cylindrical surface to be finished and inclined to the direction of feed. They derive a geometric relation for the height of the peak in the finished surface in terms of the rate of tool feed and other geometric parameters. Allowing for difficulties in interpretation of several statements due to the English constructions (translation), the relation is still not at all apparent to this reviewer, nor is the philosophic basis which would expect such a relation. Experimental results with steel and aluminum do not agree with theoretical conclusions; some agreement with brass. As the authors say "—the influences of feed (rate) is not clear." General conclusions are of little consequence. C. C. Osgood, USA

880. Paslay, P. R., Calendering of a viscoelastic material, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-1, 7 pp.

R. F. Gaskell in 1950 solved the calendering problem of a viscous material. In his solution, elastic effects of the material were not considered. In the present paper an approximate solution is obtained for a material exhibiting both elastic and viscous behavior. The formation of the Maxwell material equation is obtained and the stress-deformation-rate relations are derived. In the solution of the problem, a steady-state process and a plane strain condition are assumed. A mathematical solution of the problem is shown and a numerical solution of the approximate equation is also contained in the paper. In the conclusion the velocity gradient, $\partial u/\partial y$, in the viscoelastic case is compared with that in the viscous case. The solution may be of use to manufacturers who use the calendering process.

C. T. Yang, USA

881. Fukui, S., Kudo, H., and Seino, J., Study on impact extrusion method for nonferrous metals, *Rep. Inst. Sci. Technol. Tokyo* **11,** 9, 29 pp., 1957.

This report, comprising 29 pages, gives a detailed account of extensive experimental work carried out by the authors on the indirect extrusion process. In addition to the impact extrusion mentioned in the title a considerable number of slow-speed extrusions were made. Metals employed were aluminum and its alloys, copper, yellow brass, zinc, and lead. Blanks of materials were formed into cylindrical shells by slow-speed backward extrusion in a material testing machine and by high-speed backward extrusion in a mechanical crank press. Variables investigated were dimension and shape of extruding tool and blank, working temperature and speed, applied lubricant and surface finish of tool. The effects of the different working conditions on the hardness, failures caused, and surface state of the extruded shells were also studied. From the results of these experiments, an empirical formula for estimating the maximum extruding pressure is derived.

The paper should be of great interest to designers and users of this type of equipment, as it contains much useful data. There is little theoretical work, although authors have attempted to correlate maximum extruding pressures with what has been called the "flow stress" of the metal at strain 0.5, and with the Vickers hardness number. Both translation and reproduction are good, and the paper is logically arranged, the effect of each variable being written as a separate section, together with results and discussion.

J. M. Alexander, England

882. Shchapov, N. P., Influence of cold working on the strength of steel parts (in Russian), *Trudi Vses. n.-i. in-ta zh.-d. transp.* no. **77**, 136 pp., 1953; *Ref. Zh. Mekh.* 1956, Rev. 5590.

Results are given of the experimental investigation of the change in the strength characteristics during cold-working by bending and of the influence of the work-hardening effect on the life of the metal; the influence of heat treatment upon the effect of cold-working of steel articles, subjected, fundamentally, to inhomogeneous cold-working, the strength during repeated plastic deformation of parts with a hard slightly plastic surface layer; the admissibility of cold-working of railway axles, train bar frames, and rail metal.

The following conclusions are given:

(1) A cold-worked article, as a result of the presence of residual stresses, easily changes its shape if forces act on the article which are opposite in sign to those used during its working. The necessity is confirmed of completely prohibiting the cold-working of axles.

(2) Cold-working as a rule lowers the impact toughness at all test temperatures.

During the working of rail metal, in many cases the impact toughness is considerably (but not catastrophically) reduced and the cold shortness is increased. Therefore in recovery rails, working is permitted on the same basis as in the production of rails in factories.

(3) The influence of working is completely removed by heat treatment, by heating up to 650–700°. The hardening effect is almost removed, therefore heating to these temperatures may be recommended if there is no reason for fearing the growth of grain in the process of recrystallisation of the worked metal.

(4) The temperature of 680–700° is the minimum at which the hot-working of the articles should be completed.

(5) Cold-working is more harmful than is usually believed.

V. I. Vlasov, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

883. Majors, H., Jr., Studies in cold-drawing. Part I. Effect of cold-drawing on steel; Part II. Cold-working 2S-O aluminum, *Trans. ASME* **77**, 1, 37–48, 49–56, Jan. 1955.

In both papers the effect of drawing 1-in. diam rods down to 11/16 in. in various sequences is reported. Properties investigated were tensile, torsion, and hardness. Microstructure was studied and residual stress measurements made. In the case of steel, a limited number of impact tests were carried out to investigate the effect of drawing sequence on the transition temperature. For both metals it is concluded that the properties are affected in a similar manner. The tensile yield strength has very little effect, and sequence in drawing has no effect on the true stress-strain diagram in tension. The results of the torsion tests are inconclusive, and further work is suggested. Hardness is independent of drawing sequence and no variation in hardness across a section was observed. Microstructure was found to be uniform across section and very little affected by sequence. Residual stress was found to be greatly affected both in magnitude and distribution.

F. Ellis, England

884. Volkova, T. I., and Fedyaev, V. I., Equipment and method for testing the relaxation of plane springs (in Russian), Problems of the metal working of steam turbine materials, Moscow, Mashgiz, 1955, 57–69; *Ref. Zh. Mekh.* 1956, Rev. 5540.

A description is given of an appliance for testing plane springs (dimensions 175 × 25 × 1.5 mm) for relaxation of stresses due to bending and high temperatures.

Relaxation of the initial stress is determined from the multiple measurement of the plastic bending of the previously cooled and unloaded specimen.

Measurement of the bending is performed with the aid of a special electro-micrometer with an accuracy of 0.01 mm.

F. S. Churikov, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

885. Volkova, T. I., Tseitlin, V. Z., and Petropavlovskaya, Z. N., Method of relaxation testing during tension in a special appliance (in Russian), Problems of metal working of steam turbine materials, Moscow, Mashgiz, 1955, 70–80; *Ref. Zh. Mekh.* 1956, Rev. 5580.

It is noted that the method used at the present time in several laboratories for testing metals for relaxation with the aid of a ring of equal resistance to bending is unable to give reliable quantative characteristics of the relaxation resistance of components working under tension at high temperature.

In order to obtain these characteristics another test method is recommended for relaxation with the aid of a special appliance developed in TsNIITMASh.

The appliance consists of a massive hollow mandrel made of the same material as the test specimen, into which is inserted a cylindrical specimen $d = 6$ mm having two graduation lines which register its working portion for a length of 100 mm.

One of the heads of the specimen serves as a support, and the other has a thread for screwing on a nut, with the aid of which the required tension of the specimen is produced. The screwing-on of the nut is effected with the aid of an appliance which makes it possible to obtain the desired deformation of the working part of the specimen with an accuracy of 0.002 mm. The mandrel together with the elongated specimen is placed in a furnace and heated to test temperature.

The relaxation of the stress is determined by repeated measurement of the plastic deformation of the working portion of the specimen, previously cooled and unloaded, produced over specific intervals of time. Measurement of the deformation is performed on a universal microscope (or other instrument) with an accuracy of 0.002 mm.

In the authors' opinion, this simple appliance makes it possible to perform duration relaxation tests, enables numerous measurements of the plastic deformation to be made with sufficient accuracy, and insures the constancy of the total deformation of the specimen in the relaxation process.

F. S. Churikov, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

886. Callcott, T. G., Ball mills and ball milling (Part I), *Brit. Coal Util. Res. Assoc. Bull.* **21**, 3, 101–120, Mar. 1957.

887. Callcott, T. G., Ball mills and ball milling (Part II), *Brit. Coal Util. Res. Assoc. Bull.* **21**, 4, 153–171, Apr. 1957.

Hydraulics; Cavitation; Transport

(See also Revs. 935, 977, 1065, 1068)

Book—888. Boss, P., Elements of technical hydromechanics [Grundlagen der technischen Hydromechanik], München, R.

Oldenbourg, 1956, 59 pp. DM 10.60 (paperbound). (Reprinted from *Das Gas- und Wasserfach*)

Author, a leading authority in Germany, endeavors to present the contemporary science of hydraulics in the 50 pages of a small booklet, which contains hydrostatics, energy equation, uniform flow in channels and conduits, two-dimensional movement of water, impulse-momentum principle, potential movement and flow net, unsteady flow. This short review of different fields of hydraulics can serve as a refresher for some principles and most important problems. Booklet can be used by engineers as a short outline. S. Kolupaila, USA

Book—889. Idelchik, I. E., Hydraulic resistances (Physical and mechanical principles) (in Russian), Moscow-Leningrad, Gosenergoizdat, 1954, 316 pp.; *Ref. Zh. Mekh.* 1956, Rev. 5181.

Contents are: Introduction; chap. 1: Entry of the flow into pipes and channels; chap. 2: Flow in the case of a sudden change in the section of the pipe or channel; chap. 3: Flow in the case of a smooth change in the section of pipes and channels; chap. 4: Motion and a flow through orifices; chap. 5: Motion of a flow in throttle appliances and labyrinths; chap. 6: Resistance dispersed over the section; chap. 7: Variations in the direction of the flow; chap. 8: Fusion and separation of flows; chap. 9: Exit of the flow from the pipe or channel; chap. 10: Flow along straight pipes and channels.

The monograph is devoted to the problem of hydraulic resistances during the movement of liquids and gases in pipelines. Local losses of pressure are chiefly examined, considerable space being given to an exposition of the actual theoretical and experimental investigations of the author. The resistances along the range of the flow are briefly discussed in chapter 10.

Chapter 1 gives formulas for determining the pressure loss at entry in various entry conditions and forms of the inlet, and a comparison with the experimental data is also given. In chap. 2 relationships for determinimg the pressure loss are suggested which take into account the nonhomogeneity of distribution of velocities over the section. Chapter 3 is devoted to description of the flow structure in diffusers and to methods of calculating the resistance of diffusers. Further, relationships are given for determining the hydraulic resistances to flow through submerged orifices of varying design, and throttle, pressure, and regulating appliances.

Chapter 6 examines pressure losses in grids, lattices, various filtering elements, etc. Chapter 7 considers the influence of various factors (Reynolds number, relative roughness, geometrical parameters) on the conditions of motion in channels and diversions, and also methods for improving the working of elbows with the aid of guide vanes. A. D. Al'tshul', USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

Book—890. Wallner, J., Flood flow and 100 years of hydraulic control (in German), Jahrbuch no. 2, 10 pp. + 26 plates, 1957.

Influence of engineering work on the flood magnitude and duration is investigated, and variations are represented graphically with contour lines. River Main in Germany was investigated, as a particularly excellent example: river was regulated for average flow before 1840; its canalization, started in 1883, is almost finished. An important study for river regulation design. S. Kolupaila, USA

891. Morikawa, G. K., Non-linear diffusion of flood waves in rivers, *Comm. pure appl. Math.* **10,** 2, 291–303, May 1957.

Author considers the behavior of hydraulic waves with resistance. Equations of problem are: the equation of continuity and the usual hydraulic equation of motion.

In the paper is considered the propagation velocity U of waves, and it is found in first approximation that $U \geqslant (3/2)\, v_0$ if v_0 is the velocity in channel. Further developments for small value of the wave height λ show that

$$U/v_0 = (3/2)\,[1 + (\lambda/4) - (\lambda^2/24) \ldots\ldots]$$

Reviewer thinks that result is already known but obtained in a different manner [see Ramponi, Atti, Second Congresso della Unione Matematica italiana, Bologna, 1940]. G. Supino, Italy

892. Velikanov, M. A., Modern conceptions on the dynamic structure of flood water streams (in Russian), Vopr. geologii Azii. Vol. 2. Moscow, Izd-vo Akad. Nauk, SSSR, 1955, 397–403; *Ref. Zh. Mekh.* 1956, Rev. 6067.

Book—893. Frank, J., Unsteady processes in the supply and discharge channels of hydroelectric power plants [Nichtstationare Vorgange in den Zuleitungs- und Ableitungskanalen von Wasserkraftwerken], Berlin, Springer-Verlag, 1957, xi + 333 pp. DM 48.

Book covers two aspects in the design of hydroelectric plants: unsteady flow in open channels and in pressure conduits with surge tanks. The phenomenon of waterhammer is only briefly mentioned, without indication as to what extent it may be neglected.

Compared to the first edition (1938) the book has been thoroughly revised and enlarged; author has made his book as up to date as possible. The two lists of references cover the important publications in the western world.

The treatment of open channel flow is built up by simple mathematical means. The behavior of a disturbance in a canal with constant cross section, gradual and sudden transitions in cross section, multiple disturbances, bottom slope, wall resistance and side weirs are considered. Secondary phenomena, wave trains at the fronts of disturbances and influence of side weirs thereon, are treated quantitatively, with results of laboratory investigations given. This part ends with chapters of power plants in cascade with storage reservoirs and open conduits in between, and a special treatment of transients in a conduit partially flowing full and partially with free surface.

Reviewer regrets that author does not make use of graphical methods of characteristics. Most of the computations would then become much simpler and more surveyable. In the second part, closed conduits with surge tanks are analyzed in detail. From the simple shaft to complicated tanks with chambers on various levels, chambers with thresholds or lips at the entrance, damping restrictions in the riser, differential regulators and tanks with overflow are treated with various graphical and numerical methods of computation for quick, gradual, and periodic change of flow. Tanks with closed air chambers, tanks in conduits downstream of power-plants, and pump storage plants are treated as well. A general review is given of particular cases, such as many surge tanks on one conduit and combinations of power canals for one plant. Completely rewritten is the chapter on stability of power generation, the base for the link between hydraulic and electromechanical parts. Author pays due attention to influences of mechanical regulating devices on the hydraulic systems. Perhaps the treatment of stability could be given from a broader point of view, e.g., with the aid of methods usual for regulating and control systems. Now it has the character of a number of recipes.

The appearance of the book is excellent, as is usual for the publisher. H. J. Schoemaker, Holland

894. Gaddini, B., Abrupt change of cross section in an open canal (in Italian), *Ric. sci.* **27,** 3, 730–742, Mar. 1957.

Author describes the flow conditions and the relationship between the height upstream and downstream of the water surface in both directions of flow. P. Franke, Germany

895. Szesztay, K., Graphical aids for computation of flow in open channels and conduits (in Hungarian), Res. Inst. for Water Resources, Budapest, 1957, no. 2, 14 pp. + 14 nomograms.

A set of skillfully designed nomograms for solution of practical problems in computation of irrigation and drainage canals and pipelines. The formula by Colebrook is adapted, as revised by Crump and Lamont. An old formula by Kennedy is applied for nonsilting channels. Nomograms (in metric units) may be very useful tool for hydraulic engineers. S. Kolupaila, USA

896. Murota, A., On the flow characteristics of channels with a distributary, *Technol. Rep. Osaka Univ.* **6,** 115–122, Mar. 1956.

Conformal mapping is used to compute the amount of water diverted from a main channel by an inclined distributor. The results are in fair agreement with experiment.

C. S. Yih, USA

897. Aleksin, M. D., and Nikolaenko, E. N., The construction of curves in water channels of triangular and rectangular sections with free surface (in Russian), *Sb. stud. nauch. rabot. Klar'kovsk. avtomob.-dor. in-ta* no. 9, 5–9, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5926.

Accepting A. A. Uginchuc's interpretation of the exponent of conservation of the potential energy "t", authors modify the basic equation of irregular movement and develop an expression determining the length of the part with free surface between depths of "b_1" and "b_2" for triangular and rectangular sections.

A. M. Latyshenkov, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Incompressible Flow: Laminar; Viscous

(See also Revs. 727, 760, 888, 925, 929, 939, 941, 943, 946, 965, 966, 969, 978, 993, 1010, 1048, 1052, 1059, 1060, 1061, 1062, 1063, 1068, 1071)

898. Stewartson, K., Magneto-hydrodynamics of a finite rotating disk, *Quart. J. Mech. appl. Math.* **10,** 2, 137–147, May 1957.

Author considers the effect of a vertical magnetic field on the motion of a shallow dish of mercury, part of whose base is rotating while the rest is fixed. Both in the absence of the field and when the field is large, there is a steady solution in which the mercury is either uniformly rotating or at rest, there being a thin friction layer separating the two regions. Comparison with experiment suggests that the flow in the absence of the field is unstable but that the motion is stabilized by the field while it is still not large enough to make substantial modifications to the velocity field in the friction layer.

From the author's summary by F. D. Bennett, USA

899. Cowling, T. G., The dynamo maintenance of steady magnetic fields, *Quart. J. Mech. appl. Math.* 10, 2, 129–136, May 1957.

Author combines the Lorentz force and Maxwell equations applicable to dynamo maintenance of a magnetic field into a single integral equation. For all flow patterns for which dynamo maintenance is known to be impossible, viz., for two-dimensional, axisymmetric, and toroidal motions, the integral equation can be transformed to yield an expression for the rate of change of magnetic field with time in terms of positive or negative definite forms. From these the impossibility of a steady dynamo follows. While the number of general classes of motion to which this argument applies is limited, author suggests that the only complete proofs of steady-state dynamo impossibility must be of this type. F. D. Bennett, USA

900. Agostinelli, C., Magnetic hydrodynamic motion in a rotating cylindrical fluid, of interest in cosmogenics (in Italian), *Atti Accad. Sci. Torino Cl. Fis. Mat. Nat.* **90,** 479–508, 1955–1956.

901. Lambrecht, J., and Alvermann, W., Atomization of fuel in jet engines (in German), *Motortech. Z.* **18,** 10, 318–321, Oct. 1957.

The requirements and characteristics of fuel injection in jet engines differ significantly from those in diesel engines, inasmuch as the injection is continuous and not intermittent, the fuel quantities are much larger, and space and time for combustion are small; furthermore, the energy of injection also should be kept small. The design of nozzles for turbojet engines (not for ramjet engines) is discussed; these are of the centrifugal type, producing a spray of 80 to 100 deg cone angle. The main dimensions of the nozzle which influence the Reynolds number, and hence the turbulence and spray characteristics, are: the length and diameter of the nozzle orifice, and the diameter, number and eccentricity of the tangential orifices serving the swirl chamber. The concepts of "efflux rate" and "flow number" are explained. The atomization is influenced also by the fuel properties, in particular by the viscosity and, to a lesser extent, by the surface tension, and by the density (temperature and pressure) of the combustion air. The concepts of "specific surface" of the spray, and the "mean Sauter diameter" of the droplets forming the spray are explained. The main types of nozzles: (a) "simplex" nozzles having constant exit orifice, (b) nozzles with variable orifice, depending on the fuel pressure, (c) "duplex" nozzles having two coaxial atomizing systems, (d) "return-flow"-type nozzles in which part of the supply fuel is returned to the tank, and (e) rotating-disk atomizers are discussed and illustrated.

K. J. DeJuhasz, Germany

902. Dempster, J. R. H., and Sodha, M. S., On secondary atomization of droplets, *Jet Propulsion* **27,** 8 (part 1), p. 896, Aug. 1957.

903. Davies, H. J., and Ross, A. J., A jet deflected from the lower surface of an aerofoil, *Quart. J. Mech. appl. Math.* **10,** 3, 291–301, Aug. 1957.

Authors consider a thin symmetrical airfoil with a jet issuing from a general point on the lower chord in a general direction. The motion is assumed two-dimensional and steady and the fluid assumed inviscid and incompressible. The jet is assumed not to mix with the mainstream fluid. An iterative solution is proposed, the solution starting with an assumed jet shape. As judged by the numerical example, the solution converges slowly. It is not clear, from the paper, whether the solution given approximates the experimental data better than the theory of D. A. Spence [*R.A.E. Rep. Aero.* 2568, 1955]. W. Daskin, USA

904. Benjamin, T. B., Wave formation in laminar flow down an inclined plane, *J. fluid Mech.* **2,** 6, 554–574, Aug. 1957.

Two-dimensional disturbances are studied theoretically in the gravity flow of a liquid film at low Reynolds Number (R) with surface tension. The perturbation stream function is $f-(y)\exp(i\alpha(x-ct))$, where x is parallel to the flow direction and y normal to it. The function $f(y)$ is an ascending power series in y, satisfying the Orr-Sommerfeld equation. The series coefficients are evaluated up to the third order in αR. The results are simplified for long waves.

For flows inclined at less than the vertical, a critical Reynolds number (R_c) is found, below which no waves can grow. For a vertical flow $R_c = 0$, sufficiently long waves being always unstable, although the maximum rate of growth is very slow when $R < 4$, accounting for the apparent critical Reynolds Number observed experimentally.

An apparent disagreement with C.-S. Yih's earlier results [AMR 9, Rev. 487] is satisfactorily resolved in a postscript.

A. H. Armstrong, England

905. Rafales-Lamarka, E. E., The hydrodynamic bases of the theory of concentration in pulsating streams (in Russian), *Gorn. Zh.* no. 10, 37–39, 1953; *Ref. Zh. Mekh.* 1956, Rev. 6070.

An investigation is made of the movement of a spheroidal solid body in a continuous mono-dimensional stream of liquid. A differential equation is constructed to show the movement of the body, taking into account the resistance of the center according to the quadratic rule.

There are misprints in the formulas; in the expression for the force of inertia, instead of v there should be V; in the differential equation, the equality sign in square brackets should be replaced by the minus sign, and others.

A. M. Pirverdyan, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

906. Yeh, H., Sears function in unsteady flows, *J. aero. Sci.* **24,** 7, 546–547, July 1957.

907. Gupta, S. C., Slow broad side motion of a flat plate in a viscous liquid, *ZAMP* **8,** 4, 257–261, July 1957.

Neglecting the terms of inertia, introduction of a velocity function φ

$$u = z\cdot\varphi_x\ ,\ v = z\cdot\varphi_y\ ,\ w = z\cdot\varphi_z - \varphi$$

enables integration of simplified Navier-Stokes equations in the form

$$p = p_0 + 2\mu\cdot\varphi_z\,.$$

This allows formulating the boundary conditions in terms of φ and its first derivatives, both on the plate and at infinity. Furthermore, φ satisfies Laplace equation in virtue of continuity condition, and the problem is thus reduced to the same as that of determining the electrostatic potential φ of a conducting disk kept at a constant potential in vacuum.

General treatment is applied to the case of a circular disk, and an elegant solution is worked out by means of a Legendre transform of φ. Drag calculation result agrees with Ray's result [*Phil. Mag.* (7) **21,** 1936]. For arbitrary disk shapes a solution may be found experimentally by a simple electrostatic analogy.

P. Schwaar, France

908. Frolov, M. A., On the evaluation of ventilation aperatures (in Russian), *Nauch. tr. Novocherkas. politekh. in-ta* **26,** 17–33, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5838.

In view of the absence of data for the calculation of the resistance of two or more ventilation openings placed next to each other, author has carried out special experimental studies on a laboratory scale, which enabled him to establish the dependence of the coefficient of resistance of the openings on the corresponding distance between them. In order to express this dependence, author gives empirical formulas, while, in order to simplify the calculations for the dimensions of the windows (openings) placed as described, nomograms are presented. An example is given of the calculations.

I. E. Idel'chik, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

909. Chernov, A. P., A two-phase free flow (in Russian), *Izv. Akad. Nauk Kaz. SSR, Ser. Energ.* no. 8, 82–94, 1955; *Ref. Zh. Mekh.* 1956, Rev. 6061.

Article is dedicated to the experimental investigation of the regular movement of particles in two-phase (dust-laden gas) free turbulent flows. Two-phase flows have their practical application in various production processes (combustion of coal dust mixtures, pneumatic transport, etc.).

With the object of bringing out the qualitative side of the problem, computations were made of the movement of solid particles in a free gas stream. These calculations show that the velocity of the comparatively small particles (50μ) is markedly different from that of an airstream.

A free dust-carrying flow from a nozzle of 25-mm diam was examined experimentally. The solid particle admixtures comprised corundum powder, sand, boric acid powder, passed through the appropriate sieves.

The speed of the particles was determined photographically with stroboscopic illumination. As the result of a scrutiny of the photographs taken of the particle trajectories, graphs were made of the particle velocities, and also profiles of the particle velocities and of the air. As the result of the trials, a graph was obtained of the coefficient of particle resistance as a function of the Reynolds number. The experiments have established the presence of rotary motion of the solid particles in the flow, and also that, in a wt/wt concentration of particles in the two-phase flow less than 1 kg/1 kg, the presence of the particles does not affect the aerodynamics of the flow. In such cases the velocity of the air can be determined in the same way as for a single-phase flow.

Yu. F. Dityakin, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

910. Duncan, W. J., Analysis of a vector field and some applications to fluid motion, *Aero. Quart.* **8,** 3, 207–214, Aug. 1957.

Author gives a general analysis of a vector field using the basic idea of field line, which is such that its tangent at any point is parallel to the vector field there. Relations are obtained for the rates of change of certain quantities along the tangent, principal normal and binormal to the field line. Some applications to fluid motion are given. Results obtained are not new, but treatment is of interest.

G. Power, England

911. Hughes, R. R., Use of modern developments in fluid mechanics to aid chemical engineering research, *Indust. Engng. Chem.* **49,** 6, 947–955, June 1957.

Compressible Flow, Gas Dynamics

(See also Revs. 721, 781, 911, 932, 940, 942, 944, 947, 952, 961, 968, 979, 983, 1037, 1054, 1058)

912. Hughes, W. F., and Osterle, J. F., On the adiabatic Couette flow of a compressible fluid, *ZAMP* **8,** 2, 89–96, 1957.

Paper deals with the flow of an ideal gas with a linear viscosity-temperature dependence through a narrow passage between two parallel plates of infinite width. The heat generated by viscous stresses is partly stored in the gas and partly conducted away through the plates. There are two limiting cases, the isothermal and the adiabatic case. The isothermal case was treated by Harrison in 1913 who showed that no pressure gradient occurs along the passage if the plates are not tilted. The other case, the adiabatic Couette flow, is examined in the present paper. The mathematical treatment of this problem is much more difficult, because of the variation of temperature; also, viscosity and density vary. It becomes necessary to solve the momentum and the energy equations simultaneously with consideration of the equation of state for ideal gases and the viscosity-temperature relation. In order to succeed in their calculation, authors must assume that pressure, temperature, and also density and viscosity are constant across the narrow gap, and further that the viscosity increases linearily with the coordinate along the passage. That the latter assumption gives a good approximation is shown by the fact that

with it a temperature distribution is obtained which is also nearly linear, as it must be if viscosity should increase linearly.

The calculation yields that, in the adiabatic case because of the so-called thermal-wedge-effect, a pressure gradient is built up along the direction of flow, which may become important for high relative velocities of the plates. U. Rost, Germany

913. Oswatitsch, K., and Ryhming, I., The effect of compressibility in plane blade cascades of large turning angle (in German), *Dtsch. Versuchsanstalt Luftfahrt Rep.* 28, 29 pp., Mar. 1957.

An approximate calculation method is presented for obtaining the compressible flow through any given blade cascade, if the solution for the incompressible flow through this same cascade is known. Using the streamlines and potential lines of the incompressible solution as coordinates, rigorous involved equations are given for the incompressible case. These latter equations are then rendered quite simple and readily applicable by judicious approximations involving stream filament analysis. Solutions obtained by this method are then compared to those obtained by more lengthy, and presumably more rigorous, methods with satisfactory agreement.

E. J. McBride, USA

914. Ray, M., Two-dimensional source or sink in a compressible fluid, *Bull. Calcutta math. Soc.* **48**, 2, 69–74, June 1956.

Problem is treated including viscosity and heat conduction, with Prandtl number 1/2. Analytic solution is found by ignoring dissipation and neglecting $(u_1/u)^4$ in equation of motion, where u_1 is reference value of velocity u. Reviewer fails to understand how flow quantities are constant outside circle where $u = u_1$. Interested reader should compare Hess' numerical solution under slightly different assumptions on gas properties [AMR **5**, Rev. 2894]. M. D. Van Dyke, USA

915. Dorfman, A. Sh., and Shvets, I. T., Certain particular cases in solving equations for the boundary layer in a compressible fluid (in Russian), *Prikl. Mat. Mekh.* **19**, 4, 509–512, July/Aug. 1955.

Authors say equations for the boundary layer in a compressible fluid have been solved only for constant stream velocity, i.e. zero pressure-gradient.

They give a solution for a further class of stream velocity distributions, assuming, always, that Prandtl number = 1, viscosity is proportional to temperature, and no heat transfer to body.

They introduce new variables ξ, η, (5) said to be analogous to Dorodnitsin's variables. Variables ξ, η are related by integral relations with coordinates X, Y and with gas arguments. With help of ξ, η, and a stream function ψ, authors obtain, from general equations, a special form of equation in partial derivatives (16) having the property that for the particular stream velocity distribution $U = c\xi^m$ (17) which can be transformed into the common differential equation

$$\Phi''' + \Phi'' \Phi = \frac{2m}{m+1} (\Phi'^2 - 1) \quad (20)$$

where $\Phi(r)$ and r are new variables related to ξ, η, ψ. Authors say (20) is of the same form as the known boundary-layer equation for incompressible fluid for $U = CX^m$, whose solutions are tabulated.

In the exceptional case $m = -1$, equation (20) degenerates into

$$\Phi''' - \Phi'^2 + 1 = 0 \quad (22)$$

also equal to that of incompressible fluid (having solutions only for $C > 0$, accelerated stream.)

Finally, authors give a transformation permitting a return to the old arguments X, Y. For integer atomicity of the gas, specially for air $k = 1, 4$, solution takes a simple analytical form.

Reviewer notes a parameter α participating in definition of variables (5) is determinated *after* giving to velocity distribution the special shape (17), and so the constancy of α obliges to maintain that distribution. According to this, authors title their paper, "Certain particular cases...." However, the possibility of varying C and m gives to expression (17) certain flexibility; and, therefore, reviewer believes, authors' solution may be of practical interest. Their mathematical deductions are done in an elegant manner.

Two bibliographical references in Russian are given.

N. Krivoshein, Argentina

916. Takano, A., Transonic flow past the two-dimensional wedge with detached shock wave, Parts I, II, *J. Japan Soc. aero. Engng.* **4**, 25/26, 38–44, Feb./Mar. 1956; **4**, 34, 280–286, Nov. 1956.

In these two papers an analytic solution of the transonic flow problem is given which involves only the transonic similarity parameter. The author has started from Tricomi's equation for small disturbances for irrotational inviscid transonic flow. The boundary-value problem is formulated in the hodograph plane and is reduced to a purely subsonic boundary-value problem (this is identical with the method used in AMR **4**, Rev. 4530 and AMR **6**, Rev. 2303). The solution is expressed as an infinite series of terms involving Bessel functions, the coefficients of these terms being chosen to satisfy the boundary conditions along the sonic line and the shock polar.

In part 1, the nonlifting wedge is considered. The pressure distribution agrees closely with that predicted by other methods, but there is considerable difference in the predicted position of the shock wave. Author suggests that better agreement would be obtained by taking more terms in the series.

In part 2, the small perturbation theory is used for the lifting wedge. There is good agreement with other methods for both the pressure distribution and the local lift-curve slope.

A. W. Babister, England

917. Muller, E.-A., The decay of disturbances due to the turning of a shock wave through a sharp corner of small angle in a channel of constant cross section (in German), *Z. Flugwiss.* **5**, 4, 114–120, Apr. 1957.

Author investigates the problem of a shock of arbitrary strength proceeding along a two-dimensional uniform channel and encountering a sharp bend of small turning angle (channel width unchanged). An analysis is made with the use of the method of images and the basic similarity solution obtained by M. J. Lighthill [AMR **3**, Rev. 2716] for the same problem with only one wall. The asymptotic end-state is found and it is shown that the final shock strength is unchanged, and that the center streamline approaches the new direction of the channel with a correction term that varies at $t^{-3/2}$, where t is time. P. Chiarulli, USA

918. Whitham, G. B., On the propagation of weak shock waves, *J. fluid Mech.* **1**, 3, 290–318, Sept. 1956.

Paper extends author's previous work [AMR **6**, Rev. 961] to three space dimensions and time. The propagation of a shock-headed disturbance is treated by introducing the concept of rays and ray tubes (as in geometrical acoustics). Assuming the energy in each tube is conserved, flows may be described as functions of ray tube area and time; the resulting two-variable problem is solved. Solution is nonlinear in its treatment of energy dissipation in shock, though allowing the rays to retain their linear position proves acceptable. In the present paper the singularity arising from the intersection of rays is not dealt with.

Interesting examples presented include unsymmetrical explosions, supersonic bangs, supersonic flow past cones and wings of finite span.

An ingenious method of treating otherwise intractable many-variable problems. R. Hetherington, England

919. Hayes, W. D., The vorticity jump across a gasdynamic discontinuity, *J. fluid Mech.* **2,** 6, 595–600, Aug. 1957.

Author deduces the jump in vorticity across a discontinuity surface in an inviscid gas flow using only the following dynamical jump conditions: (1) No jump in the normal component of (nonzero) mass flow; (2) no jump in the tangential component of velocity; (3) jump in normal component of momentum equal to force acting on gas. The discontinuity surface considered can be arbitrary in time and space, except that the curvature must be defined.

The method used in the derivation is to equate the tangential gradient of the pressure jump across the discontinuity with the jump in the tangential pressure gradient. The results show that the only jumps which contribute to the jump in vorticity are jumps in certain functions of the density. These density jumps are multiplied by quantities which are continuous across the discontinuity, namely, functions of the normal component of mass flow and functions of the tangential component of velocity. For the case of a shock wave of general shape in uniform flow, the results reduce to those of M. J. Lighthill [title source **2,** 1–32, 1957]. The salient feature of this work is that the author's analysis goes through without assumptions on the composition or thermodynamic properties of the gas.

H. A. Stine, USA

920. Taganov, G. I., Drag due to lift in supersonic flow (in Russian), *Prikl. Mat. Mekh.* **20,** 3, 382–394, May-June 1957.

Author reviews previous work on drag due to lift in subsonic incompressible and compressible flow. Purpose of the paper is attempt to show whether so-called wave and induced drags of supersonic flow are mechanically necessary to create lift and cannot be eliminated just as the corresponding drag for wings satisfying the Munk condition in incompressible fluid flow or for an ideal propeller in incompressible flow, or whether the parasitic drag is a part of the afore-mentioned supersonic drag. Three theorems are formulated: *Theorem 1.* At small angles of deflection of the stream from the lifting apparatus, the coefficient of the mechanically necessary or ideal drag is one-fourth the square of the lift coefficient if the nondimensional coefficients are obtained by referring the force to the area of the equivalent jet deflected by the lifting apparatus. *Theorem 2.* A wing-plate of infinite span in a supersonic flow has an additional parasitic drag equal in magnitude to the mechanically necessary or ideal drag when lift is created. *Theorem 3.* A lifting disk, which is a degenerate case of a wing cascade of arbitrary shape in a plane perpendicular to the direction of the unperturbed supersonic flow and is of zero thickness in the direction of the stream whose flow is isentropic and whose small angle of deflection is constant in the whole plane of the disk, does not have any parasitic drag in creating lift.

M. D. Friedman, USA

921. Ryhming, I., On the nonstationary two-dimensional supersonic flow around a suddenly inclined thin plate (in German), *Dtsch. Versuchsanstalt Luftfahrt Ber.* 35, 23 pp., May 1957.

Author calculates nonstationary two-dimensional supersonic flow around a thin plate suddenly inclined by a small angle of incidence, using the linearized potential equation with time-dependent terms. This leads to a wave equation having standard solution. After discussing the regions of integration, writer performs the integration in five regions into which the plate is divided. Differentiation of the disturbance potential gives the velocity-components pattern over the plate at a certain time after the sudden inclination took place. This assumption corresponds to a constant ϑ-component over the plate. Sudden motion of plate originates a wave whose characteristic properties are well studied by the writer. Problem was schematically described in Sears ["General theory of high-speed aerodynamics," Vol. VI, Princeton University, 1954 by Lomax and Heaslet, Section D, Chapter 6] and a similar problem was attacked by Badrawy [*Mitt. Inst. Aerodyn., ETH, Zürich,* no. 19, 1952].

M. Z. v. Krzywoblocki, USA

922. Mueller, J. N., Equations, tables, and figures for use in the analysis of helium flow at supersonic and hypersonic speeds, *NACA TN* 4063, 12 pp. + 1 table + 15 figs., Sept. 1957.

Report parallels air flow references, such as *NACA Rep.* 1135. Perfect gas relations for one-dimensional flow, shock, and expansion waves are given. Tables of dimensionless ratios are given as function of Mach number. Oblique shock characteristics for wedges and cones are shown for Mach 12, 16, 20, 24. Helium viscosity is shown as function of temperature.

H. R. Ivey, USA

Wave Motion in Fluids

(See also Revs. 781, 840, 891, 893, 904, 1058, 1069, 1074)

923. Brillouet, G., Study of some problems in connection with gravity waves (in French), *Publ. sci. tech. Min. Air, France* no. 329, 144 pp., 1957.

Paper gives a general and critical review of the problem of water waves on sloping beaches. By examining the properties of the singularities of the solution, author proves that for a given amplitute and phase angle at infinity there is only one advancing wave which is physically admissible.

T. C. Lin, China

924. Longuet-Higgins, M. S., The refraction of sea waves in shallow water, *J. fluid Mech.* **1,** 2, 163–176, July 1956.

Wave refraction is examined, in the first instance, with the aid of wave number diagrams, which offer an ingenious method of interpreting, for simple cases, the principal derivations of this paper that, as short-crested waves enter shallow water, (a) mean wave length decreases, with crest alignment tending to parallel the shore, (b) crest length increases relative to wave length (and usually absolutely), (c) crests become staggered, echelon fashion, owing to skewness or deviation of "envelope" direction from crest direction. Main analysis treats a continuous spectrum of waves, comprising a narrow band of frequencies and directions, with preferred wave number and direction. Straight coastline with parallel depth contours is assumed. On basis that energy density remains unaltered by refraction (reflection nil), author evaluates conditions which govern changes in the average number of waves in a "group", their angular deviation from mean direction, and the skewness of the waves. Results are valid, strictly, only for waves of small amplitude. Amplitude is shown to diminish first and then to increase in shallow water, inversely proportional to fourth root of depth. It is shown also that number of waves in a group is doubled in process of reaching shallow water. Finally, author examines case of mixed spectrum, such as locally developed short-crested sea and a superimposed swell, and concludes that the longer waves will be amplified more than shorter ones and crest lengths will increase.

Numerical examples of results are given. Reviewer considers paper to be of great elegance and novelty; its limitation is that it may be valid only for the assumed case of straight coastline and parallel depth contours, since Snell's law, in the form used, would not generally apply to concave or convex coastlines. It would appear Eq. (4.4) is in error (probably misprint), since following equation is correct.

B. W. Wilson, USA

925. Sretenskii, L. N., Cauchy-Poisson problem for the separation surface of two flow surfaces (in Russian), *Izv. Akad. Nauk SSSR, Ser. geofiz.* no. 6, 505–513, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5198.

First of all a class of particular solutions of the Laplace equation is sought

$$\varphi_1(x, y, t) = F_1(t)\, e^{k(y+ix)},$$

$$\eta = kH(t)\, e^{ikx}$$

$$q\, \varphi_2(x, y, t) = F_2(t)\, e^{-k(y-ix)},$$

which satisfy the conditions for union of the pressures on the division line of the flows and also kinematic conditions. Here φ_1 and φ_2 are the velocity potentials of the upper and lower flows, $\eta = \eta(x)$ is the division line. The functions which were found are used for construction of the Fourier integral which gives a formal solution of the Cauchy-Poisson problem in the form

$$\varphi_1(x, 0, 0) = f_1(x) \quad \varphi_2(x, 0, 0) = f_2(x)$$

The integral found is convergent at very strict limitations, which were imposed on the character of the tendency to zero of the functions f_1 and f_2 at $|x| \longrightarrow 0$. The detailed analysis is given for the case when

$$f_1(x) = e^{-b^2x^2}, \quad f_2(x) = 0$$

In this case the solution is convergent. A number of the properties of the wave motions obtained were investigated. In particular it is shown that the wave front, as in the classical Cauchy-Poisson problem, is propagated with constant acceleration. However, the phenomenon studied also has a number of properties which distinguish it from the phenomenon of wave propagation in the usual problem. Thus, for example, author determines an almost strict periodicity of fluctuations of the level of the liquid at a given point, which does not occur in the usual Cauchy-Poisson problem.

N. N. Moiseev, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

926. Bovichkovskaya, T. V., The aerodynamic conditions using solid wave-movement models (in Russian), *Trudi Mor gidrofiz. in-ta Akad. Nauk SSSR* **6,** 98–106, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5936.

Results are published of the velocity and pressure calculations of the air stream in a wind tunnel, using solid models of wave movement of various profiles. It was shown that when $b/\lambda = 0.1$ the air flow round the wave is almost streamline; when this ratio is increased, vortices are formed, the maximum pressure is transferred towards the crest of the wave, the windward and leeward sides of the wave are subject to uneven pressure, and, because of this, there is an increase in the force applied to the crest and operating in the direction of the moving stream of air. Photographs are shown of the air-stream lines around the wave profiles.

S. V. Zhak, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

927. Gorodetskii, S. F., A stereophotogrammatical survey of wave motion when modeling hydrotechnical installations (in Russian), Nauch. tr. Odessk. in-ta inzh. mor. flota. Yubileinyi vyp., Moscow, 1955, 176–192; *Ref. Zh. Mekh.* 1956, Rev. 5950.

A description is given of a variation in construction of stereophoto assemblies, found and tried in the investigation. All the formulas calculated are cited, with expressions to cover errors. Methods of photography are indicated, and the examination of the results of stereophotogrammatical surveys of swell formation are given.

Ya. L. Sekrzh-Zen'kovich, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

Turbulence, Boundary Layer, etc.

(See also Revs. 945, 979, 982, 990, 1001, 1002, 1048, 1054)

928. Sedney, R., Some aspects of three-dimensional boundary layer flows, *Quart. appl. Math.* **15,** 2, 113–122, July 1957.

Author reexamines the equations for the three-dimensional laminar boundary-layer flow along smooth surfaces in light of recent advances in three-dimensional boundary-layer theory. By the use of certain mathematical properties of these equations and by discriminate choice of coordinates he derives a useful criterion for the occurrence of secondary flow in the boundary layer and an expression for the displacement thickness in the presence of secondary flow.

J. R. Weske, USA

929. Yeh, H., Boundary layer along annular walls in a swirling flow, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-22, 22 pp.

The development of incompressible turbulent boundary layers along concave and convex stationary annular walls is investigated analytically and experimentally for a swirling flow, i.e., flow with both tangential and axial mean velocities. It was found that the integral momentum equation describing this type of boundary layer contains three correction terms to the conventional equation. The combined influence of these corrections appears to promote the growth of the boundary layer next to a concave wall. Other differences between the boundary layers with swirl and those without swirl are pointed out and interpreted. Measurements on turbulence intensities appear to confirm such interpretations.

From author's summary by S. Corrsin, USA

930. Sanyal, L., Three-dimensional boundary-layer equations, *ZAMM* **37,** 5/6, 169–177, May/June 1957.

Paper deduces in a rigorous analysis the three-dimensional boundary-layer equations following the method given by Schmid and Schroder for the two-dimensional case. Author states clearly all necessary assumptions and hypotheses and confirms Howarth's intuitive results for the first two equations [AMR **4,** Rev. 3640], but obtains some deviations for the third one.

K. Pohlhausen, USA

931. Garner, H. C., Thickness parameters by rapid integration of turbulent boundary layer profiles, *J. roy. aero. Soc.* **61,** 556, 278–281, Apr. 1957.

The velocity distribution in a turbulent boundary layer is represented by a polynome containing four independent constants. It is then shown that the displacement thickness and the momentum thickness are functions of the velocity at two particular distances from the wall (y/δ = (0.15 and 0.62) and of one parameter. This remaining parameter is closely related to the ratio H of the two thicknesses, and author selects a best value. It is then sufficient to measure the velocity at the edge of the layer and at the two specified distances in order to determine the displacement thickness and momentum thickness. Author does not discuss the physical processes involved.

R. Betchov, USA

932. Tinkler, J., Effect of yaw on the compressible laminar boundary layer, *Aero. Res. Counc. Lond. Rep. Mem.* 3005, 10 pp. + 1 table + 4 figs., 1957.

The equations governing the laminar compressible boundary layer on a yawed body of infinite span are transformed to give three nondimensional equations defining two velocity components and the enthalpy. Assuming that the Prandtl number is unity and that there is zero heat transfer, a relation is obtained between the stream Mach number and the angle of yaw for flows which give the same boundary-layer equations. The further assumption of viscosity proportional to the absolute temperature is made and "simi-

lar" solutions, obtained from a differential analyzer, are presented for a range of two controlling parameters.

From author's summary by E. V. Laitone, USA

933. Burrows, F. M., A theoretical and experimental study of the boundary layer flow on a 45° swept back wing, *Coll. Aero. Cranfield Rep.* 109, 56 pp. + 3 tables + 35 figs., Oct. 1956.

The laminar boundary layer was calculated for a 45° sweptback wing, and detailed measurements of pressure distribution and boundary-layer profiles were made in flight on a wing mounted as a dorsal fin on an Avco Lancaster. The angle of attack was varied from 0 to 10°. The wing was a double ellipse. Great care was taken to produce a smooth lacquer finish. A "fence" prevented the boundary layer on the fuselage from flowing over the wing. Author concludes from tuft studies that disturbances at the blunt trailing edge do not cause transition to occur near the leading edge. No laminar flow was detected on either surface over the angle of attack range at Reynolds numbers over 1.55×10^6 per foot.

A. M. Kuethe, USA

934. Savulescu, S., Method for investigating boundary layer characteristics (in Rumanian), *Acad. Repub. pop. Rom. Comun.* **6,** 7, 877-883, 1956.

Method is outlined for determining boundary-layer characteristics under general conditions (laminar, turbulent, with heat transfer, incompressible and compressible) based on introduction of variables $\xi = x/L$; $\eta_\delta = \psi/\psi_\delta$ instead of variables x and y where $\psi = \int_0^y \rho u dy$ and L is a reference length. Motion equations are transformed in function of new variables, obtaining a system of equations having diffusion equation structure, for which a method of solving by successive approximations is given, where first approximation is in most cases sufficient.

Some examples of applications of method are further given: (a) flat plate in laminar regime with constant temperature at wall; (b) flat plate in turbulent regime with constant temperature at wall; (c) flat plat in laminar regime with uniform suction. Results are obtained in simple and explicit form, agreeing with those obtained by Th. Karman and H. Tsien [*J. aero. Sci.* no. 9, 1934], E. van Driest [*J. aero. Sci.* no. 3, 1950; AMR **4,** Rev. 3641], and R. Iglisch [Veröffentl. Math. Inst. Tech. Hochsch., Braunschweig, 1944], respectively.

V. N. Constantinescu, Rumania

935. Cooke, P. W., The hydraulics of drilling mud flow, *J. Inst. Petrol.* **43,** 399, 69-85, Mar. 1957.

The problem of removing caved debris from a well bore is discussed and calculations are given to demonstrate that turbulent flow in the annulus is desirable. The removal of drilled cuttings presents no problem under either turbulent or laminar flow conditions for any mud weight as long as a minimum annular-space velocity of about 1 ft/sec is maintained. If laminar flow has to be accepted because of pump pressure limitations, it would seem desirable to keep the yield value and plastic viscosity of the mud to a minimum and increase the mud weight within reasonable limits.

From author's summary

936. Hsu, C. S., Vortex-ring cascade and a conjectured model of transition to turbulence, *J. aero. Sci.* **24,** 4, 313-314, Apr. 1957.

In the study of turbulence the mechanism which governs the transition from instability to full turbulence has not yet been clearly understood nor has the development of a tripped transition. It is the purpose of this note to report an interesting vortex-ring cascade phenomenon observed and to present a conjectured model of transition to turbulence. The model seems particularly suited for phenomena of tripped transition.

From author's summary

937. Gregory, N., Walker, W. S., and Johnson, D., Part I, The effect on transition of isolated surface excrescences in the boundary layer; Part II, Brief flight tests on a Vampire I aircraft to determine the effect of isolated surface pimples on transition, *Aero. Res. Counc. Lond. Rep. Mem.* 2779, 23 pp., 1956.

In part I, the effect of isolated surface excrescences in a laminar boundary layer in producing disturbances which may lead to turbulent flow has been examined experimentally by several methods. Photographs of some of the flow patterns visualized by smoke and china-clay techniques are given.

The critical heights of pimple which just give rise to spreading wedges of turbulent flow have been measured on a flat plate and on two airfoils at several angles of incidence. The results are analyzed and are presented in a form which enables approximate estimates to be made of the protuberances permissible on laminar-flow surfaces at full-scale flight Reynolds numbers. The estimates suggest that at an altitude of 30,000 ft the critical pimple height is 0.004 in. for a speed of 350 mph, while 0.002 in. may be permissible at all subsonic speeds. At sea-level, however, the tolerances are approximately halved.

The method given in part I is an empirical method based on wind-tunnel tests made at the National Physical Laboratory at wind speeds up to 200/ft/sec and airfoils of 30-in. and 60-in. chord (maximum Reynolds number of approximately 3×10^6). To provide information at flight Reynolds numbers, two flights have been made on a *Vampire* aircraft indicating the effect of tiny paint pimples on the laminar boundary layer at a Reynolds number, based on wing chord, of 25×10^6 near sea-level. Part II describes these tests.

From author's summary

938. Titchener, I. M., and Taylor-Russell, A. J., Experiments on the growth of vortices in turbulent flow, *Aero. Res. Counc. Lond. curr. Pap.* 316, 8 pp. + 9 figs., 1957.

Measurements of the flow in turbulent line vortices along the center of a pipe have been made to determine the growth of trailing vortices in the wake of an airplane. It is found that the rate of growth is small and of the same order as for a laminar line vortex.

From authors' summary

939. Sleicher, C. A., Jr., Experimental velocity and temperature profiles for air in turbulent pipe flow, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-9, 9 pp.

Paper describes the experiments and results for obtaining the ratio of eddy diffusivity for heat to that for momentum. A well-thought measuring instrumentation produced consistent results in the region *Re* 14,000-80,000. Inlet temperature to the pipe (1.5-in. diam) was approximately 80 F, and the electrically heated walls 15-20 F higher. Near the wall, the ratio was found to approach a constant ~ 1.4, but in all cases it was above unity. An extensive bibliography is included.

M. Rand, Canada

Aerodynamics of Flight; Wind Forces

(See also Revs. 769, 796, 820, 860, 903, 920, 926, 933, 956, 958, 959, 962, 987, 1013, 1979, 1073)

940. Grant, F. C., The use of pure twist for drag reduction on arrow wings with subsonic leading edges, *NACA TN* 4104, 20 pp. + 3 tables + 4 figs., Aug. 1957.

Linearized-theory calculations of the drag reduction achieved by applying the first three terms of a power series for twist to flat delta wings are presented. In addition, the reductions due to applying linear twist to a family of flat arrow wings are presented. The results cover the speed range of subsonic leading edges.

The results show a 6% drag reduction due to twisting a flat delta wing with sonic leading edges and a steady decrease in the gains as sweepback increases.

For the family of linearly twisted arrow wings investigated (that with sonic trailing edges), the maximum drag reduction is 2% in the medium sweepback range with a steady diminution in both directions. A beneficial effect of increasing aspect ratio obscures the twist effects in this case. The convergence to the optimum-power-series twist appears to be rapid.

From author's summary by H. C. Levey, Australia

941. Helmbold, H. B., Limits of airfoil lifts (in German), *Ing.-Arch.* **25**,4, 273–277, June 1957.

The Prandtl lifting-line theory is used to calculate the lift and reduced drag of a monoplane wing, taking into account the downwash angle of the trailing vortices. Due to this angle, the induced downwash at the lifting line is inclined forward (upstream) and thus, when compounded with the free-stream velocity, results in a Kutta-Joukowski force vector which is inclined downstream more than the amount shown by the usual theory. As a result of this additional rotation of the force vector, the lift passes through a maximum in the lift-drag polar and eventually becomes zero, when the force vector has been rotated into the downstream direction. Maximum value of the reduced lift coefficient (coefficient divided by aspect ratio) is 1.90, for which the induced drag coefficient (reduced) is 2.40 and the downwash angle of the trailing vortices is 21.6°.

A. Roshko, USA

942. Hunter-Tod, J. H., The aerodynamic derivatives with respect to a rate of yaw for a delta wing with dihedral and at incidence at supersonic speeds, *Aero. Res. Counc. Lond. Rep. Mem.* 2887, 19 pp. + 7 figs., 1957.

Expressions are developed on the basis of an unsteady flow analysis for the yawing derivatives for a delta wing with small dihedral at small incidence flying at supersonic speeds. The assumptions of the linearized theory of flow are made throughout; only first-order terms in the rate of turn are considered.

The terms dependent on the dihedral alone are continuous and decrease numerically with rising Mach number. The remaining terms are discontinuous at a Mach number at which a leading edge becomes supersonic; in particular, the rolling-moment component due to incidence changes sign; the other derivatives may do likewise in certain instances.

The approximate theory developed in the paper breaks down as a leading edge nears the Mach wave from the vertex of the wing. The yawing amplitude for which the results quoted present reasonable approximations decreases rapidly as this condition is approached; in particular, the contributions of the leading-edge suction become undefined.

Earlier results based on strip theory are greater numerically than those derived in the present paper by significant amounts that increase with Mach number and aspect ratio. The two theories agree for vanishingly small aspect ratios.

From author's summary by E. V. Laitone, USA

943. Weber, J., The calculation of the pressure distribution over the surface of two-dimensional and swept wings with symmetrical aerofoil sections, *Aero. Res. Counc. Lond. Rep. Mem.* 2918, 44 pp. + 13 tables + 10 figs., 1956.

Paper is based on the theories of F. Riegels and H. Wittich [Yearbook Dtsch. Luftfahrt 1942, p. 1–120; *Ing. Arch.* **XVI**, 1948, p. 373; ibid. **XVII**, 1949, p. 94] and presents a complete derivation, including the effects of approximations made on the accuracy of the results. The procedure is most practical, requiring knowledge of the airfoil ordinates only, and is applicable to two-dimensional airfoils of finite thickness, at angles of attack in incompressible potential flow. The pressure distributions calculated by this method are identical with the exact values for elliptical airfoils, and the agreement with exact values for Joukowski airfoils is excellent. Method is also applied to swept wings of infinite span, and to the center section of swept wings.

H. P. Liepman, USA

944. Kuchemann, D., A simple method for calculating the span and chordwise loading on straight and swept wings of any given aspect ratio at subsonic speeds, *Aero. Res. Counc. Lond. Rep. Mem.* 2935, 52 pp., 1956.

Theory is applicable to uncambered wings at subcritical Mach numbers and is essentially an interpolation between the limiting cases: Prandtl theory for large-aspect-ratio unswept wings or for infinite sheared wings; R. T. Jones theory for very small-aspect-ratio straight or swept wings; Kuchemann's theory for the kinked center section and tip section of large-aspect-ratio swept wings.

Spanwise loading is obtained from Prandtl's lifting-line equation modified by a downwash factor ω which depends upon aspect ratio and sweep. Formula is chosen such that it fits values and behavior at limits corresponding to wings of large and small aspect ratio, swept and unswept. Chordwise loading is characterized by a single parameter n, related to ω and, for swept wings, also to spanwise position.

Calculation of chordwise and spanwise loadings and section aerodynamic center are shown to be in excellent agreement with experiment and other more elaborate theoretical calculations.

A. M. Rodriguez, USA

945. Poisson-Quinton, P., Some physical considerations on blowing out air along airfoils (in German), Jahrbuch, Wissenschaft. Gesellsch. Luftfahrt 29–51, 1956.

Two applications of blowing out air along airfoils, namely boundary-layer control and circulation control, are considered. Boundary-layer control is achieved by blowing out air tangentially in those zones where separation would otherwise occur. Thus, blowing over a flap gives the flap its theoretically possible effectiveness up to considerable angles of deflection. By blowing near the leading edge the angle of incidence for maximum lift will be increased. The blowing energy required is of such a size that it can easily be taken from the compressor of a jet-engine serving for propulsion.

Circulation control by blowing near the trailing edge leads to considerable lift coefficient values; however, the blowing energy required has the size of the total energy produced by the jet-engine.

Blowing may also be applied to reduce drag on profiles having position of maximum thickness far rearward.

H. Gortler, Germany

946. Niemz, W., Supplement to the incompressible wing theory of E. Truckenbrodt (in German), Jahrbuch, Wissenschaft. Gesellsch. Luftfahrt 130–133, 1956.

An improved method for Truckenbrodt's airfoil theory (Jahrbuch, Wissenschaft. Gesellsch. Luftfahrt 40–65, 1953) is presented, giving a better evaluation of effects due to trailing-edge sweep. Same amount of computational work is required except that fewer points than anticipated are required at the kinks of a swept wing.

S. Lampert, USA

947. Keune, F., and Oswatitsch, K., On the influence of the geometry of slender bodies of revolution and delta wings on their drag and pressure distribution at transonic speeds, *Roy. Inst. Technol. Div. Aero., Stockholm, KTH-Aero TN* 42, 34 pp., 1956.

According to the area rule, the flow about slender bodies can be computed as superposition of the flow about an equivalent body of revolution and a cross-sectional flow. Paper applies this approach to a family of bodies, for which the distribution of cross section is expressed by polynomials. Many details are worked out so that immediate engineering applications become feasible.

G. Guderley, USA

948. James, H. A., and Hunton, L. W., Estimation of incremental pitching moments due to trailing-edge flaps on swept and triangular wings, *NACA TN* 4040, 19 pp. + 1 table + 8 figs., July 1957.

Low-speed incremental pitching moments due to flap deflection on swept and triangular wings have been estimated from span-loading theory, two-dimensional airfoil data, and simple sweep theory. For some 58 cases, comparison of the estimated pitching moments with the measured experimental pitching moment indicated a deviation of about 0.02. Report provides a rapid, fairly accurate method of calculating pitching moment for a wide variety of types of trailing-edge flaps on wings of arbitrary planform.

R. M. Crane, USA

949. Robbins, Claire I., and Silberstein, J. P. O., The directional stability of an aircraft on a tricycle undercarriage with automatic steering, *Aero. Res. consult. Comm. Australia. Rep.* SM. 245, 20 pp. + 9 figs., Sept. 1956.

The equations of motion of an aircraft when its tricycle undercarriage has an automatically steered nose wheel are derived. The equations of motion are nonlinear and are solved by a step-by-step method which reduces them to linear form. Using the Hurwitz criteria, the stability of the system is studied and values for the steering parameters that induce stability are determined. The deviation of the actual motion from the desired path of the aircraft is studied, and it is determined that an improper choice of the steering parameters leads to instability of the yaw angle.

L. A. Pipes, USA

950. Scruton, C., Woodgate, L., and Alexander, A. J., Measurements of the aerodynamic derivatives for swept wings of low aspect ratio describing pitching and plunging oscillations in incompressible flow, *Aero. Res. Counc. Lond. Rep. Mem.* 2925, 35 pp., 1957.

The aerodynamic lift and moment derivatives for pitching oscillations in incompressible flow have been measured for two axis positions on (1) a clipped delta wing of aspect ratio 1.2, (2) a complete delta wing of aspect ratio 1.6, and (3) an arrowhead wing of aspect ratio 1.32. The results for the arrowhead wing and the clipped delta wing are compared with values predicted by the vortex-lattice and the Multhopp-Garner methods of calculation. The results for the complete delta wing are compared with values calculated by Garner and by Lawrence and Gerber. In each of the comparisons a satisfactory measure of agreement was found between the theoretical and experimental values of the derivatives. Calculated values for the clipped delta wing based on very low aspect ratio theory did not accord with those found by experiment.

From authors' summary

951. Lehrian, Doris E., Aerodynamic coefficients for an oscillating delta wing, *Aero. Res. Counc. Lond. Rep. Mem.* 2841, 10 pp., 1957.

A delta wing of aspect ratio 3 is assumed to be describing pitching and vertical translational oscillations of small amplitude in incompressible inviscid flow. The corresponding aerodynamic coefficients arecalculated by the method of W. P. Jones [*Rep. Mem.* 2470] for values 0.26 and 0.8 of the mean frequency parameter $\omega_m (\equiv pc_m/V)$, and certain of the coefficients are also obtained for $\omega_m \rightarrow 0$.

There is little experimental evidence available for comparison, apart from some measurements of the pitching-moment damping coefficient at low values of ω_m.

From comparisons of calculated values with experimental results for the delta wing, and other planforms, it appears that the method provides a reasonable basis for calculating flutter derivatives, but, as indicated by author, it is not satisfactory for estimating all the stability derivatives. For the calculation of the latter, a modified version of the method has been developed, [D. E. Lehrian, *Rep. Mem.* 2922], which is relatively easy to use and which should give reasonable accuracy.

From author's summary

952. Mangler, K. W., A method of calculating the short-period longitudinal stability derivatives of a wing in linearised unsteady compressible flow, *Aero. Res. Counc. Lond. Rep. Mem.* 2924, 30 pp. + 9 figs., 1957.

A method is developed for the calculation of the pressure distribution and the aerodynamic forces and moments on a wing performing harmonic pitching and heaving oscillations. The calculation is based on the assumption of inviscid potential flow without shock waves and is restricted to small incidence, so that the linearized theory is valid.

In contrast to other work in the field, the theory applies to all Mach numbers. It is restricted to small values of the reduced frequency and should be valid for the usual range of short periods occurring at present in flight. The formal solution yields two integral equations for the parts of the load, which are in phase and go out of phase with the oscillation; these are of the same form as the corresponding equation in steady flow.

The way is thus opened for solutions over the whole Mach number range at small frequencies, if the corresponding steady solutions can be found. The calculation is in fact easiest for $M = 1$ and has been done here for delta wings to supplement a previous supersonic calculation, made on different frequency assumptions, which broke down near $M = 1$. It appears from the two sets of results that the short-period oscillation will be unstable near $M = 1$, if the apex angle of the delta wing is greater than about 60 deg. This confirms a now generally recognised trend.

Such results near $M = 1$ must of course be invalidated to an unknown extent by thickness viscosity and shock waves at their maximum effect. Nevertheless it is unlikely that these factors will remove the critical nature of the transonic damping as calculated by this method. With all its obvious limitations this method, when extended to other planforms, should provide a useful tool in studying the effect of geometrical parameters on the stability of an aircraft at transonic speeds.

From author's summary

953. Neumark, S., Problems of longitudinal stability below minimum drag speed, and theory of stability under constraint, *Aero. Res. Counc. Lond. Rep. Mem.* 2983, 32 pp. + 8 figs., 1957.

Practical difficulties in cruising below minimum drag speed have long been known but not fully explained. The reasoning proposed by Painlevé in 1910 purported that flight below minimum drag speed should be fundamentally unstable, so that any speed error would lead to a divergence. This reasoning is shown to be invalid on the ground of the general theory of dynamic stability in uncontrolled flight, Painlevé's criterion being a grossly inadequate approximation to the condition of phugoid stability. However, the criterion may be fully vindicated for the case of flight controlled by the elevator in such a way as to maintain constant height. In this form, the criterion seems not only to explain qualitatively the troubles encountered in slow cruising, but also to lead to a good quantitative estimate of speed variation following an initial disturbance. The criterion also applies to the problem of ultimate height response to an elevator deflection.

The concept of stability of partially controlled flight is further developed, leading to a general theory of "stability with constraint," i.e., when a control (elevator, throttle, etc.) is used to suppress one component of the disturbance. The theory may be useful as giving approximate solutions of problems in which the pilot moves his control so as to keep one component of the disturbance always as small as possible. The principles of the theory are set out and several examples given. Flight tests are needed to explore further the validity of this method of approximation.

From author's summary

954. Payne, P. R., Helicopter longitudinal stability—some contributions to existing theory. Parts I, II, *Aircr. Engng.* **29,** 339, 143–150, May 1957; **29,** 340, 178–183, June 1957.

Assumptions made for the longitudinal downwash gradient are applied in determining downwash derivatives for forward flight. Significant parameter is "effective hinge stiffness," combining actual elastic stiffness at flapping pin with a function of skew angle (delta-3) and taper. Longitudinal flap-back angle, inclination of thrust vector to tip-path plane, and ratio of thrust to disk lag are determined and evaluated for a typical configuration. Stability equations, using these downwash derivatives, are given for a single-rotor helicopter with finite and zero hinge stiffnesses, and for a flying platform with two counter-rotating rotors. Theoretical period of typical flying platform including downwash effects is one-seventh period when downwash is neglected; experimental verification is needed. E. Welmers, USA

Aeroelasticity (Flutter, Divergence, etc.)

(See Rev. 951)

955. Beatrix, C., Energy method for the detection of modes of vibration which may give rise to flutter (in French), *Rech. aéro.* no. 58, 41–48, May-June 1957.

By carefully comparing results for separate modes and binary combinations in many degree of freedom cases (which generally reveal "energy transfers" between modes), certain modes can sometimes be cancelled (as being "unimportant") from a final complete analysis. J. H. Greidanus, Holland

956. De Vries, G., Special flutter problems connected with control surfaces and tabs (in French), *Rech. aéro.* no. 58, 49–53, May-June 1957.

It is stated that (even) mass-balanced control surfaces may give rise to flutter when rigid cables introduce strong coupling with main surface vibrations. Example is given.

J. H. Greidanus, Holland

957. Leonard, R. W., and Hedgepeth, J. M., On the flutter of infinitely long panels on many supports, *j. aero. Sci.* **24**, 5, 381–383, May 1957.

Authors investigate the flutter problem for an infinitely long panel, pin-supported at equally spaced intervals, utilizing the simple "static" air force approximation of Hayes. The exact solution of the resulting differential equation is first formulated in a manner similar to that used by the authors in a previous paper dealing with the finite pin-ended panel. With the subsequent application of matrix techniques, they are able to show that the vibration deflection shapes, in the presence of air forces, are periodic over two bays. This is in contrast to the in vacuo vibration shapes which lack this periodicity. Having established this periodicity, authors revert to a Galerkin procedure utilizing, for the panel deflection, an infinite term Fourier series periodic over the two bays, to establish a criterion for the flutter speed. The infinite series converges rapidly and the results are plotted. The results indicate that flutter involves the sin $2\pi x/L$ and 1-cos $2\pi x/L$ mode shapes rather than the lower frequency sin $\pi x/L$ mode. The infinite series solution compares favorably with a previous analysis utilizing only the two pertinent mode shapes mentioned.

Because of the use of the simpler "static" air forces, the analysis is applicable only at high Mach numbers (above about M = 1.7) and at low values of reduced frequency, which generally result from the high panel-to-air-mass ratios, $\rho_p t/\rho_A L$, typical of normal air densities, material densities, and panel dimension. The use of these "static" air forces appears to be justified in this range by comparison with results using more exact theories in previous problems.

Authors point out the importance of the boundary conditions on the flutter speed of an infinite panel. Their analysis, which considers the infinite panel as pin-supported at equally spaced intervals, yields much higher flutter speeds than another analysis by J. W. Miles which considers the infinite panel as unsupported and the flutter resulting from waves traveling down the infinite panel.

The present article appears to answer Miles' criticism of an earlier article by the authors on the same subject and helps to clarify many of the concepts involved in the flutter of infinite panels. R. L. Bisplinghoff, USA

958. Jordan, P. F., On the flutter of swept wings, *J. aero. Sci.* **24**, 3, 203–210, Mar. 1957.

The concept of a sweep parameter k which combines sweep angle and aspect ratio is developed on the basis of the streamwise strip method. Charts of reference speeds varying sweep parameter, wing density, and Mach number are shown. The theoretical possibility of bending flutter and its effect on the flutter of swept wings and of wing-body combinations are considered. T-tail flutter and improved analytical methods are discussed briefly.

From author's summary by P. A. Libby, USA

959. Richardson, A. S., Jr., On the prediction of gust and buffet response of wings and airfoils, *J. aero. Sci.* **24**, 5, 385–386 (Readers' Forum), May 1957.

960. Williams, D., Solution of aeroelastic problems by means of influence coefficients, *J. roy. aero. Soc.* **61**, 556, 247–251, Apr. 1957.

Author discusses use of aerodynamic and structural influence coefficients for analyzing aeroelastic behavior of low-aspect-ratio lifting surfaces. Attention is given to case in which different sets of stations are used for the aerodynamic and structural analysis; rather elementary means are employed to convert to a common set.

This paper is evidently intended to further Dr. Williams' campaign to encourage more use of large high-speed digital computers in Britain. Reviewer notes that the procedures outlined have been in use in America for several years.

J. M. Hedgepeth, USA

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 858, 893, 913, 954, 977, 1013, 1049, 1055)

961. Kondo, K., On the potential-theoretical fundamentals of the aerodynamics of screw propellers at high speed, *J. Fac. Engng. Univ. Tokyo* **25**, 1, 39 pp., Jan. 1957.

This is a summary of author's former work. Author applies Prandtl's acceleration potential to the theory of screw propellers with small thrust in subsonic compressible flow. Starting from the wave equation, the velocity potential of a simple pole in circular motion is represented by a series of definite integrals involving products of Bessel functions. Applying the Lorentz transformation, the potential of a simple pole in helical motion is obtained. The potential of the dipole is derived by differentiation. Assuming slender straight blades and calculating the downwash at the propeller disk, the boundary-value problem is represented by a simple integral equation which can be solved by methods known for the lifting-line theory.

Author proves four theorems of A. Betz and T. Moriya, the first time this has been done for compressible flow. Numerical calculations of propeller characteristics will be reported in another paper.

Reviewer believes that the same potential method has been applied independently by H. Billing and H. Merbt [*ZAMM* **29**,

pp. 267, 301, 1949] to calculate the sound generation of screw propellers. H. G. Kussner, Germany

962. Stewart, W., Second harmonic control on the helicopter rotor, *Aero. Res. Counc. Lond. Rep. Mem.* 2997, 15 pp., 1957.

Author presents a theoretical investigation of the effect of imposing second harmonic control on the helicopter rotor. The usual assumption of inflow constant over rotor disk is made. Fourier series for flapping angle is terminated after second harmonic. The main effect obtained is a more even distribution of incidence and loading on the disk. This could be used to postpone stalling limitation of forward speed to a higher tip-speed ratio. However, a serious drawback of the method would be a further complication of the rotor head.

H. Parkus, Austria

Book—963. Sass, F., Diesel engines [Dieselmaschinen], second ed., Vol. II, Berlin, Springer-Verlag, 1957, x + 475 pp.

"Diesel engines, construction and operation, a text for students" is adaptable for third- or fourth-year college instruction. A knowledge of mathematics through differential equations is desirable. The geometry of the engine dictated by the specific requirements of power application and design limitations introduces the more detailed analysis of the system. Basic equations are derived for the inherent inertia forces and resulting couples due to reciprocating and rotating masses; tables are presented summarizing the results for two- and four-stroke-cycle in-line engines for various crank arrangements. The application to V-type engines and nonsymmetrical crank arrangements are briefly discussed. Torsional analysis includes the determination of the equivalent spring-mass system, frequency of oscillation, amplitudes, nodes, and resulting stresses in the engine and coupled load. Several examples are presented and compared with torsiograph records. Various types of torsional dampers are discussed and their influence on the system illustrated. Extensive use is made of the force polygon in the foregoing analyses. A brief discussion of the torsiograph completes this section of the first 147 pages.

Two-hundred and sixty-one pages are devoted to a detailed review of the construction and operation of engines manufactured by 10 European firms. Excellent drawings of sectioned components of the various engines serve to illustrate the text material. Mechanical or turbo-supercharging of some of the engines discussed is briefly covered for two- and four-stroke-cycle engines.

A general discussion (31 pages) of operation and maintenance concludes the text. This is an excellent companion text to "Solid injection diesel engines" by the same author.

C. J. Vogt, USA

964. Brown, E. I., A comparison of hydraulic and pneumatic accessory power generation, *Trans. ASME* **79,** 6, 1284–1290, Aug. 1957.

Aircraft accessory-power transmission systems utilizing hydraulic pumps and motors are shown to be more efficient than those using pneumatic turbines driven by compressor bleed. The hydraulic system shows significant advantages in terms of both engine maximum thrust and cruise fuel consumption. A convertible hydraulic unit used as a turbojet starter motor and as an engine-driven hydraulic pump offers weight and performance advantages which further increase the value of hydraulics for all aircraft accessory-power systems. From author's summary

965. Rohlik, H. E., and Wintucky, W. T., Investigation of semivaneless turbine stator designed to produce axially symmetrical free-vortex flow, *NACA TN* 3980, 39 pp., Apr. 1957.

A semivaneless turbine stator designed to eliminate blade wakes and secondary-flow accumulations of boundary-layer air was built and tested. Performance of this stator was evaluated with static pressures measured in the vaneless section and surveys of total pressure and flow angle made at the stator exit.

The experimental results indicated that the semivaneless stator set up free-vortex flow which was substantially free of circumferential gradients in flow angle and total pressure. Loss in total pressure across this stator was slightly greater than that measured with a conventional stator designed for the same exit flow conditions. Radial distribution of momentum loss indicated that the slight additional loss appeared at the inner wall.

From authors' summary

966. Blakeley, T. H., and Darling, R. F., The development of refractory nozzle blades for use in high-temperature gas turbines, *Trans. N. E. Cst. Instn. Engrs. Shipb.* **73,** 5, 231–252, Mar. 1957.

The operating temperatures of gas turbines are dependent on the properties of the blade material. Since the advent of the jet engine, immense strides have been made in the improvement of metallic alloys, and long-life gas turbines can now be designed to run at temperatures up to about 1400 F, but this development is probably nearing its limit. In order to achieve a fuel economy comparable with that of a marine diesel engine, the operating temperature must be raised to something of the order of 2200 F, and this will clearly require cooling of the blades or, alternatively, the use of nonmetallic materials.

The existence of high centrifugal stresses in rotor blades facilitates cooling by the thermosiphon principle and at the same time militates against the use of nonmetallic materials which tend to be relatively weak in tension. The stator blades, however, offer a promising field for the application of nonmetallic materials, and the present paper describes developments which have been carried out over the last eight years.

Numerous materials were tested in the laboratory under conditions designed to simulate the stresses and thermal shocks that will be encountered in service. Various methods of manufacturing the required blade shapes were also investigated, and the shapes themselves were modified to some extent so as to meet the special requirements of the materials. Cascades of blades were tested in a high velocity gas stream at temperatures up to 2200 F. Several materials were found to have reasonably good thermal shock resistance, and creep strength at high temperature appeared to be the most serious limitation. At least one material has emerged which seems likely to fulfil the necessary requirements. A single-stage turbine embodying refractory stator blades in conjunction with a liquid-cooled rotor is now in course of development.

From authors' summary

967. Capetti, A., Equilibrium operating conditions of gas turbine-compressors (in Italian), *Aerotecnica* **37,** 1, 3–6, Feb. 1957.

Author considers a turbine mechanically coupled only to an aerodynamic compressor with fixed speed ratio as used in the gas generator section of turbojet and some turbopropeller engines.

A method to study the variations of turbine-inlet temperature and of the speed of the turbine-compressor combination is described. This method applies when the pressure ratios through the first turbine nozzles and the following propelling or turbine nozzle are both lower than the critical value.

Having formulated the two basic equations which define the equilibrium conditions, a graphical method for their solution is given. From author's summary

968. Costedoat, M., Le Manach, J., and Maillet, E., General analysis of subsonic flow in a helico-centrifugal compressor (in French), *ONERA Publ.* no. 86, 42 pp., Feb. 1957.

An overcharging compressor with helicoidal axial flow, and straight radial blades (296-mm diam), has been carefully tested. Highest pressure ratio attained at 16,000 rpm. i.e., at 60% of

nominal speed, was 1.6, Mach number at diffusor entrance 0.6. Axial part which has been analyzed as blade series is denoted as a critical section of the whole compressor, having an efficiency of about 50%. Due to the favorable behavior of the radial part at greater outputs the maximum efficiency of the whole wheel is over 90%. Irregular distribution of velocities and influence of pressure pulsations—both of which diminish the efficiency of radial part at lower air flows—have been studied. Diffusor efficiency declines at greater outputs to as low as 80%, the losses at the entrance into its blades being three times greater than the influence of friction. Losses in the spiral casing are sensible at full load only.

Although the scope of investigations has been limited by the output of the driving motor, the results may be useful for other than the given type of compressor.

O. Mastovsky, Czechoslovakia

969. Louis, J. F., and Horlock, J. H., Some aspects of compressor stage design, *Aero. Res. Counc. Lond. curr. Pap.* 319, 12 pp. + 7 figs., 1957.

Authors aim to improve accuracy in "off-design" stage analysis of axial flow compressors with low hub-tip ratios by including variation of axial velocity along blade height. Actuator theory of Bragg & Hawthorne [AMR **4**, Rev. 864] is used to give the flow through inlet guide vane-rotor-stator combination and the resulting expressions are linearized. Assuming that the outlet angle from a blade row remains unaltered with incidence—which is nearly true up to stall—solutions are obtained for a series of different angular distributions.

Using Howell's cascade theory [*R & M* 2095], the blade performance can be related to the flow solutions, and the "off-stage" performance assessed. Further, the radial position at which blade stall first occurs can be found and presumably the stage characteristic improved by suitable re-design.

F. G. Blight, Australia

970. Horlock, J. H., Instrumentation used in measurement of the three dimensional flow in an axial flow compressor, *Aero. Res. Counc. Lond. curr. Pap.* 321, 4 pp. + 8 figs., 1957.

Measurements of total pressure, static pressure, and yaw angle between the blade rows of an axial flow compressor have been made with a variety of previously calibrated instruments and the results of these investigations are compared.

Good agreement between the instruments is obtained except in the boundary layers near the walls of the compressor.

From author's summary

971. Scanlan, J. A., and Jennings, B. H., Free-piston engines and compressors, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-23, 3 pp.

The free-piston engine, not too many years ago, appeared to be of significance mainly as an unusual form of air compressor. Current interest, however, shows the free-piston engine to be most important as the compressor-gasifier unit of a gas-turbine power plant. Such a gasifier-turbine combination represents one extreme of the compound engine, with the entire useful mechanical power delivered by the turbine alone. This combination is promising because the turbine, in compact size, provides good starting torque and delivers a smooth and flexible output. The reciprocating-type combustion chamber operating at high pressure develops exceptional thermodynamic efficiency under intermittent temperatures far higher than those which can be employed continuously with present turbine materials. The free-piston engine also can serve as a source of high-pressure, high-temperature air for industrial purposes. One application of this nature is related to the rejuvenation of static oil fields by forcing high-temperature, high-pressure gas into them. The hot gasses fluidize the viscous oils trapped in the sands and make additional recovery of oil possible.

An excellent bibliography covers a literature search from 1927 to 1956 and is believed to be complete, although it is realized that errors of omission may exist. Most of the references were checked for accuracy as to source and general content.

From authors' summary

972. Turner, R. C., and Hughes, Hazel P., Tests on rough surfaced compressor blading, *Aero. Res. Counc. Lond. curr. Pap.* 306, 18 pp. + 19 figs., 1956.

973. Dhara, P., Choosing a centrifugal or axial flow pump, *J. Instn. Engrs., India* **37**, 7 (part 2), 707–713, Mar. 1957.

974. Rotta, J., Ejector pumps with extremely high flow rate ratio (in German), *Forsch. Geb. Ing.-Wes.* **23**, 157–167, 1957.

Ejectors with very large values (order 50) of the ratio of flow-of-transported to flow-of-driving air are discussed theoretically. Experiments on small ejectors of this type are described.

N. H. Johannesen, England

975. Wenzel, L. M., Hart, C. E., and Craig, R. T., Experimental comparison of speed-fuel-flow and speed-area controls on a turbojet engine for small step disturbances, *NACA TN* 3926, 56 pp., Mar. 1957.

Optimum proportional-plus-integral control settings for control of engine rotational speed with fuel flow were determined by minimization of integral criteria. The optimum settings thus determined correlated well with analytically predicted optimum settings.

At the optimum control settings, the speed overshoot ratio was 1.28; simulated turbine blade temperature did not overshoot. The optimum control settings were not appreciably altered by the limitation of the rate of change of fuel flow.

The frequency response of engine speed to exhaust-nozzle area could be represented by a linear lag, specified by the rotor time constant, plus a dead time. The linearity of the system, however, is limited to the extent of the physically realizable area change, and thus holds only for small disturbances.

Over a limited range, speed was satisfactorily controlled by exhaust-nozzle area. Within this range, this system was found to possess certain advantages over the speed-fuel-flow control.

From authors' summary

976. Santangelo, G., On the static thrust of turbojet without and with afterburner. Limitations in the convenience of increasing the compression ratio of the compressor (in Italian), *Aerotecnica* **37**, 1, 24–28, Feb. 1957.

General expressions are given for the calculation of static performances at sea level of turbojets without and with afterburner as related to the compression ratio of the compressor.

Numerical investigations show that the maximum thrust which can be reached making use of the best heat-resistent materials at present available corresponds to values of about 20 ÷ 25 for the compression ratio.

Eventual increase of thrust is deemed possible by increasing the maximum temperature bearable by the turbine vanes.

From author's summary

Flow and Flight Test Techniques

(See also Revs. 927, 933, 970)

Book—977. Shchapov, N. M., Hydrometry of hydraulic structures and machinery (in Russian), Gosenergoizdat, 1957, 237 pp.

Water-discharge measurement is an important part of testing turbines and pumps, of investigation on spillways and other hy-

draulic structures. Many methods are known and work is being done in all countries; however, this is the first systematic treatise on this subject. Author is a pioneer in this field in Russia; he tested more than 30 power plants under various circumstances. Measurements were mostly performed with current meters: author lists 57 examples in open conduits and 20 in penstocks; these data are of particular interest. Information contained in this book is extremely large, as also are the references: 191 Russian titles, 117-foreign. The book is of great value; an English edition would be very appropriate.

There a few places only where author was unaware of work done abroad, e.g., the graphical methods of determining the Coriolis and Boussinesq coefficients. Russian method of relative conductivity in dilution method was known earlier; it was patented in Germany in 1921. S. Kolupaila, USA

978. Thurston, G. B., Hargrove, L. E., Jr., and Cook, B. D., Nonlinear properties of circular orifices, *J. acoust. Soc. Amer.* **29,** 9, 992–1001, Sept. 1957.

An experimental study of the nonlinear fluid flow properties of thin, square-edged, circular orifices is presented. Much of the work was done with water at a frequency of 22 cps, the wave length of compressional waves in the medium being very large compared with the orifice dimensions. Measurements of the pressure-flow relations were made with a hydrodynamical test system described earlier by the first-named author [title source, **24,** 6, 649–652, Nov. 1952] The cases considered were: (1) a sinusoidal volume velocity, (2) a sinusoidal volume velocity with an added steady component. The pressure differential developed across the orifice was measured by means of a capacitive-type pressure detector and was found to contain higher odd harmonics in case (1), with the second harmonic added in case (2). A pressure-flow equation for orifices is developed and applied to the two flow conditions investigated, and good agreement with the observed behavior is obtained. There is also an experimental study of the dependence in case (1) of the parameters of the pressure-flow equation on frequency, kinematic viscosity, orifice diameter, and orifice length. R. Heller, USA

979. Ludwig, G. R., Effects of probe size on measurements in a laminar boundary layer in supersonic flow, *Univ. Toronto Inst. Aerophys. TN* 9, 8 pp. + 14 figs., Nov. 1956.

Total pressure profiles are studied at $M = 2.5$ in the boundary layer on a circular cylinder. From hypotheses on the probe tip shock-wave and boundary-layer interaction, pressure profiles measured with probes of varying rectangular entrance geometry are corrected. Differences dependent on transverse probe height ($b < 0.26\ \delta$) are eliminated. Comparison with cylindrical probes and with theory is also made. Reviewer suggests that the results are strictly applicable to rectangular probes on a circular cylinder.

H. M. Spivack, USA

980. Marson, G. B., and Lilley, G. M., The displacement effect of pitot tubes in narrow wakes, *Coll. Aero. Cranfield Rep.* 107, 18 pp. + 18 figs., Oct. 1956.

The apparent displacement of the effective center of a circular pitot tube from its geometric center when placed in narrow wakes has been measured at sub- and supersonic speeds. Similar effects were found at all speeds. If the tube diameter was small compared with the wake width, the displacement was toward the region of higher velocity, and was proportional to the tube outside diameter. For larger tubes the displacement was reduced, and was reversed in direction when the tube diameter exceeded about three times the wake width.

From authors' summary by A. Roshko, USA

981. Folsom, R. G., Review of the pitot tube, *Trans. ASME* **78,** 7, 1447–1460, Oct. 1956.

Paper is an attempt to bring together the important information regarding Pitot tubes and their use; to summarize the available data on the application of various types of impact and velocity probes for the guidance of engineers and research workers; and to aid them in the design of flow instruments for specific applications.

From author's summary

982. Sato, H., Nonlinearity and inversion effects of hot-wire anemometer on the mean and fluctuating-velocity measurements at low wind-speed, *Rep. Inst. Sci. Technol. Tokyo,* **11,** 7, 73–84, 1957.

The basic nonlinearity of the hot-wire anemometer causes increasingly larger errors as the fluctuation amplitude increases and the mean velocity decreases. There were earlier attempts to assess the magnitude of the error and to devise correction methods [Martinelli, R. C., and Randall, R. D., "The behavior of a hot-wire anemometer subjected to a periodic velocity, *Trans. ASME* Jan. 1946; Corrsin, S., *NACA Wartime Rep.* W 94, 1946].

L. S. G. Kovasznay, USA

983. Laurence, J. C., and Stickney, T. M., Further measurements of intensity, scale, and spectra of turbulence in a subsonic jet, *NACA TN* 3576, 24 pp., Oct. 1956.

As an extension to the data reported in *NACA TN* 3561, hot-wire-anemometer measurements of the intensity, scale, and spectra of turbulence in a 3.5-in.-diam free subsonic jet were made for downstream distances from 8 to 20 jet diameters. The results show that the eddy size increased with distance from the jet nozzle until a maximum was reached. The position of this maximum depended upon the distance from the jet centerline. After reaching the maximum, the eddy decreased uniformly in size with distance from the nozzle.

The nondimensional mean-velocity profiles were nearly similar in a region from 12 to 20 jet diameters from the nozzle. Corresponding similarity in intensity of turbulence profiles, however, was not observed as far as 20 jet diameters downstream of the nozzle. From authors' summary

984. Bird, G. A., and Lilley, G. M., On the choice of the working fluid for intermittent supersonic wind tunnels, *Coll. Aero. Cranfield Rep.* 112, 16 pp. + 7 figs., Jan. 1957.

The general advantages and disadvantages of using a gas other than air as the working fluid in a wind tunnel are discussed. It is shown that, in certain cases, an intermittent tunnel may be more suitable than a continuous tunnel for use with these gases.

A number of gases and gas mixtures (in particular, air, Freon 12, helium and Freon 12 - Argon) are compared on the basis of their Reynolds number against Mach number characteristics when expanded from given stagnation conditions, and the limitations, which are imposed on the maximum Mach number by the condensation of the gas, are calculated. The size and complexity of the required pressure vessels and associated equipment are discussed for the different gases and some conclusions are reached as to the more suitable gases for various operating ranges.

From authors' summary

985. Winter, K. G., and Brown, C. S., Loads on a model during starting and stopping of an intermittent supersonic wind tunnel, *Aero. Res. Counc. Lond. curr. Pap.* 335, 8 pp. + 8 figs., 1957.

Measurements are given of the loads on a model during starting and stopping of an intermittent supersonic wind tunnel at Mach numbers of 2.00 and 2.48. Qualitative agreement is obtained with a simple theory but a need is evident for further measurements at higher Mach numbers.

The use of a model loading coefficient in terms of tunnel stagnation pressure is proposed.

From authors' summary

986. Williams, J., and Alexander, A. J., Three-dimensional wind-tunnel tests of a 30° jet flap model, *Aero. Res. Counc. Lond. curr. Pap.* 304, 11 pp. + 20 figs., 1957.

As a first investigation of finite-aspect-ratio effects in relation to the jet flap scheme, pressure plotting experiments were made on a small-scale model, with a 12½% thick wing section already tested under two-dimensional conditions at the N.G.T.E. The spanwise distribution of "pressure lift" loading induced by T.E. blowing was evaluated by chordwise integration of the surface static pressures, and followed closely that which would be expected for a conventional wing at incidence (without T.E. blowing). The total lift, drag, and pitching moments were derived for values of jet momentum coefficient C_J up to 2 at wing incidences between $-5°$ and $20°$, and up to 5 at zero incidence, by summing the corresponding integrated pressure forces and jet reaction components.

From authors' summary

987. de Bray, B. G., Low speed wind tunnel tests on perforated square flat plates normal to the airstream: drag and velocity fluctuation measurements, *Aero. Res. Counc. Lond. curr. Pap.* 323, 8 pp. + 6 figs., 1957.

The effects of perforations upon the drag, and velocity fluctuations downstream, of square plates normal to the air stream are described. It is shown that perforations can have a powerful effect upon the level of velocity fluctuations, particularly the low-frequency components, with only a comparatively small reduction in drag coefficient.

It is also shown that perforating the central region only of a square plate is as effective in reducing velocity fluctuations as perforating the whole plate, while giving a slightly higher drag coefficient than the latter. On the other hand, perforations near the periphery only are less effective.

From author's summary

988. Lukasiewicz, J., Van Der Bliek, J. A., and Scott, J. G., High speed systems of wind tunnel data handling, *AGARD Publications, Rep.* 17, 26 pp. + iv, Feb. 1956.

The present stage of development of instruments and data-processing equipment makes it possible to take full advantage of economy and convenience of operation of intermittent wind tunnels. In this note force and pressure data-handling systems, which consist of commercially available components and with which it is possible to handle data at a rate of better than one point per second per channel and to record it simultaneously in analog and in digital form, are described.

From authors' summary

989. Muncey, J. J., and Pote, D. M., Design and construction of wind tunnel models, *AGARD Publications, Rep.* 20, 22 pp. + iv, Feb. 1956.

990. Davies, F. V., and Cooke, J. R., Boundary layer measurements on 10° and 20° cones at $M = 2.45$ and zero heat transfer, *Aero. Res. Counc. Lond. curr. Pap.* 264, 41 pp. + 22 figs., 1956.

This note describes the measurement of boundary layers on two cones of total angles 10° and 20° in a supersonic air stream of $M = 2.45$ and under zero heat-transfer conditions.

Transition from laminar to turbulent flow occurred between four and six inches from the tip of the 10° cone at a Reynolds number between 10^6 and 1.4×10^6; the layer on the 20° cone was laminar over its entire length of six inches, i.e. up to a Reynolds number of 1.4×10^6.

Most of the laminar boundary-layer measurements were made on the 20° cone and results agree reasonably well with the flat plate solution of Monaghan transformed by the theoretical cone-flat plate relations of Hantzsche and Wendt, and Mangler.

All the data for the turbulent boundary layer were obtained from measurements made on the 10° cone and comparison with flat plate data indicates that the cone-flat plate relation is within 6% of an empirical relation analogous to the $\sqrt{3}$ laminar boundary-layer factor.

From authors' summary

991. Bratt, J. B., A note on derivative apparatus for the N.P.L. 9½ inch high speed tunnel, *Aero. Res. Counc. Lond. curr. Pap.* 269, 5 pp. + 5 figs., 1956.

A brief description is given of new equipment for measuring derivatives on finite-aspect-ratio models with trailing-edge flaps in the N.P.L. 9½-inch high-speed tunnel. Some account is also given of considerations leading to the choice of method.

From author's summary

992. Dumitrescu, L., Computation of length of shock tube component elements for a given working duration (in Rumanian), *Studii si Cercetari Mecan. appl.* **8,** 2, 337–353, 1956.

Aim of paper is to determine shock-tube elements for a given working duration. Author first studies interaction between wave shock and separation surface in one-dimensional unsteady motion. These results are first used to compute minimum length of shock-tube elements for a given working duration and to obtain a given Mach number before separation surface, and then behind separation surface.

For air, results are set in form of diagrams as well.

V. N. Constantinescu, Rumania

Thermodynamics

(See Revs. 874, 909, 911, 922, 966, 974, 984, 1011, 1015, 1016, 1017, 1018, 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027, 1028, 1029, 1030, 1031, 1032, 1033, 1034, 1035, 1036, 1064, 1075)

Heat and Mass Transfer

(See also Revs. 727, 732, 734, 795, 796, 798, 823, 901, 911, 914, 939, 990, 1044, 1050, 1052, 1075, 1076)

Book—993. Bonilla, C. F., edited by, Nuclear engineering, New York, McGraw-Hill Book Co., Inc., 1957, xi + 850 pp. $12.50.

Book is written for three types of reader. The first type is the student who is getting a degree in nuclear engineering. (There are over 250 problems.) The second reader is the practicing physicist who desires to have an appreciation of the problems of applying nuclear fission processes to produce power. The third reader is the practicing engineer who desires to understand "what is it that's different about harnessing power from fission than from combustion?" The editor has done a good job in satisfying these different types of readers and still keeping the book up to the high standard set by the first volume, "Control of nuclear reactors and power plants" by Schultz [AMR **10,** Rev. 996], of McGraw Hill series in nuclear engineering.

It is encouraging to find a book covering nuclear engineering which is more than an attempt to "get on the bandwagon" and publish a book as quickly as possible for the nuclear power information-hungry engineering public. Many of these books appear to be just thrown together and certainly would give the uninitiated a poor impression of the status of nuclear technology, and perhaps technology in general. This is not the case with the present book. Professor Bonilla has done an excellent job in assembling information written by thirteen authors on all phases of the technology that goes into reactor design. Certainly Professor Bonilla's chapters on fluid flow and heat transfer, Professor Freudenthal's chapter on thermal stress, and Mr. Hoopes' chapter on instrumentation and control are decided improvements over what the reviewer has come across in some other so-called nuclear engineering texts. The chapters covering nuclear physics aspects of the subject deal with this new subject for the engineer

in a very admirable manner. The practicing nuclear engineer will find it useful to have material related to aspects of nuclear design other than his own specialty so conveniently assembled under one cover. He can certainly start to see the "over-all" picture through this book. This is what makes the book useful. In addition, there are about 650 references.

This large 850-page book can be divided into three parts. The first part, covering seven chapters in 270 pages, deals with the physics of subatomic particles which are related to fission, nuclear instrumentation, biological health shielding, and reactor physics. The second part, on applied engineering, requires five chapters of 400 pages to cover subjects ranging over thermal stresses, heat transfer, uranium metallurgy, and reactor power-plant control. The last part of the book consists of chapters on power generation in general, nuclear reactor types, and the all-important problem of the legal aspects of nuclear power. In addition, there are 17 appendixes including technical data on engineering and nuclear cross-section data. An interesting appendix is a tabulation of existing reactors and their principal characteristics. R. S. Wick, USA

994. Boley, B. A., and Barber, A. D., Dynamic response of beams and plates to rapid heating, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57-APM-17, 4 pp.

The thermally induced vibrations of rectangular plates and beams under some typical heat applications are studied. The basic parameter of the problem, B, is found to depend on the natural frequency of the structure and on a characteristic thermal time. Curves are presented of the variation with B of the ratio of the deflections calculated including and neglecting the effect of inertia. The role of inertia is found to be important for rapidly applied heat inputs and for thin plates. An approximate formula for its rapid estimation is also presented.

From authors' summary by B. Langefors, Sweden

995. Vodicka, V., Stationary temperature fields in a two-layer plate (in Polish), *Arch. Mech. stos.* **9**, 1, 19–24, 1957.

A two-layer infinite plate is considered, assuming that the temperature on both surfaces is represented by different periodic functions of the variable x with the same period and independent of the variable y; x and y denote Cartesian coordinates in a plane parallel to the plane of the plate.

The general solution of the problem is obtained by means of superposition of solutions of two partial problems, each of them assuming variable temperature [according to the distribution law of the principal problem] on one face and zero temperature on the other face.

A solution in the form of series of trigonometric and hyperbolic functions is obtained. W. Urbanowski, Poland

996. Vodicka, V., Stationary temperature distribution in cylindrical tubes (in Polish), *Arch. Mech. stos.* **9**, 1, 25–33, 1957.

The temperature distribution is considered in two cases: (1) a two-layer infinite tube of annular cross section, (2) a tube the cross section of which has the form of three concentric ellipses. The temperature is supposed to be constant along the tube axis, its value on the outer and inner faces being determined by means of two different, in general, periodic functions which can be expanded in Fourier series.

By means of a suitable transformation of (1) polar, and (2) elliptical coordinates, author succeeds in reducing the problem to that of a two-layer plate, solved previously by himself, and in obtaining expressions determining the temperature by means of trigonometric and hyperbolic series.

W. Urbanowski, Poland

997. Przemieniecki, J. S., Transient temperature distributions and thermal stresses in fuselage shells with bulkheads or frames, *J. roy. aero. Soc.* **60**, 552, 799–804, Dec. 1956.

The temperature distribution and thermal stresses are calculated in a configuration consisting of a cylindrical fuselage shell with bulkheads or frames. It is shown that at supersonic speeds thermal stresses are set up in a conventional fuselage structure as a result of the bulkhead restraint against circumferential expansion of the fuselage skin. The thermal stresses due to restraint by fuselage frames are usually less severe. The relative merits of various combinations of materials for the skin and the bulkhead diaphragm are discussed. Furthermore, the possibility of the use of light alloy bulkheads to alleviate thermal stresses is investigated. Diagrams are given for calculating maximum thermal stresses and stress-time variation for various rates of heat input in the fuselage skin due to aerodynamic heating.

From author's summary by H. Schuh, Sweden

998. Granet, I., The numerical calculation of steady state heat transfer problems in cylindrical geometry, *J. Amer. Soc. nav. Engrs.* **69**, 2, 387–390, May 1957.

Solution of problem should be of interest to the heat-transfer field generally. Paper describes method of attack on problem of a water tube receiving plane radiation over the front half of its circumference.

Laplace's equation for steady-state heat conduction in two dimensions with no internal heat sources or sinks in cylindrical coordinates is transformed to

$$e^{-2Z}\,(\partial^2 t/\partial Z^2 + \partial^2 t/\partial\theta^2) = 0$$

by the transformation $r = e^Z$. The expression in the brackets corresponds to the Laplacian equation in rectangular coordinates for the Z, θ plane. Conventional numerical calculation technique is then applied, with special attention given to the boundary conditions. Equations are set up for a variety of boundary conditions, and method of attack given for still other conditions.

Specific problem is calculated which has been previously solved analytically by both Jakob and Dusinberre. Paper states that the results obtained by the numerical method agree for engineering purposes with the analytical solution.

C. C. Eckles, USA

999. Whiteman, I. R., and Drake, W. B., Heat transfer to flow in a round tube with arbitrary velocity distribution, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-1, 4 pp.

Paper deals with an analysis of the development of temperature profile and the prediction of Nusselt modulus due to laminar flow of a constant property fluid in a round tube with fully developed but arbitrary velocity distribution prescribed by $U = U_c[1-(r/r_0)^m]$, where U_c is velocity of the fluid at the center line of the tube, r_0 the tube radius, and m any arbitrary numeral. It is an extension of an earlier paper ["Heat transfer to laminar flow in a round tube or flat conduit—The Graetz problem extended," *Trans. ASME* **78**, 441–448, 1956] by Sellars, Tribus and Klein in which only the parabolic velocity profile is considered. The methods of treatment are virtually identical. As pointed out by Sellars, et al, since the simplified energy equation is a linear one, it is only necessary to consider the fundamental Graetz solution pertaining to constant wall temperature. Solutions for any arbitrary wall temperature and heat flux distribution in the axial direction may be constructed therefrom.

Calculated results for Nusselt modulus were shown plotted against $(x/D)[N_{Re} \cdot N_{Pr}]^{-1}$ for $m = 2, 3, 10$, and 1000. Unlike Sellars' paper, however, results were not given for the case of constant wall heat flux and linearly varying wall temperatures.

B. T. Chao, USA

1000. Ede, A. J., Hislop, C. I., and Morris, R., Effect on the local heat-transfer coefficient in a pipe of an abrupt disturbance

of the fluid flow: abrupt convergence and divergence of diameter ratio 2/1, Instn. mech. Engrs., Prepr., 16 pp., Feb. 1957.

A straight aluminum brass pipe composed of two sections (1- and 2-in. inner diam) has been heated by means of d c 5 v, 5000 amp. Local heat-transfer coefficient h has been computed from outer wall temperatures (measured by thermocouples) and from mean water temperatures (calculated from heat balance up to a given section of the tube). Nearly 60 tests were made at $Re =$ 800 – 100,000 and heat fluxes 0.01 – 3.8 watts per sq cm, and results were plotted as $Nu/Re^{0.8}\ Pr^{0.4}$ against section distance and Re respectively. An abrupt divergence has caused an increase of h 2.5 to 4 times, the influence extending as far as 20 diam, but only a rise of the order of 10% has been found immediately after an abrupt convergence. An attempt is made to extrapolate the results for a zero heat flux, and a comparison with some recent papers dealing with different entry conditions is attached. O. Mastovsky, Czechoslovakia

1001. Bray, K. N. C., The effect of heat transfer on interactions involving laminar boundary layers, *Aero. Res. Counc. Lond. curr. Pap.* 339, 6 pp. + 1 fig., 1957.

Already known methods of calculating the influence of shock waves on laminar boundary layers and their separation are generalized to the case where there is a considerable heat transfer in the boundary layer. The theory is based on some questionable assumptions. As an example of the use of this theory the boundary layer is calculated for large Reynolds numbers and for some ratios of the wall temperature to free-stream stagnation temperature. Results are given in a table; a figure shows the influence of the wall temperature on the Mach number, which causes separation. A. Betz, Germany

1002. Edwards, A., and Furber, B. N., The influence of free-stream turbulence on heat transfer by convection from an isolated region of a plane surface on parallel air flow, *Instn. mech. Engrs. Proc.* **170,** 28, 14 pp., 1956.

In wind tunnel with a working section of 12 in. square by 51 in. long the heat transfer of an electrically heated flat plate of 4 × 6 in. by forced convection was investigated in the three flow regimes: laminar, transition, and turbulent. The maximum airspeed was 120 fps. The results of the experiments are represented by the form of the Nusselt-Reynolds relation and agree well with the theoretical solutions of Pohlhausen and von Kármán. With the above conditions, once a turbulent boundary-layer flow is established, turbulence levels appear to have no influence on the heat transfer. Margot Herbeck, Germany

1003. Izumi, R., Natural heat convection inside the vertical tube, Proc. sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 393–396.

Laplace transforms are used to find velocity and temperature distributions for unsteady fully-developed natural-convection flow of a quasi-incompressible fluid; that is, the density is considered constant except in the buoyancy term. The cases of constant wall temperature and uniform heat flux at the walls are treated.

S. Ostrach, USA

1004. Ostrach, S., Unstable convection in vertical channels with heating from below, including effects of heat sources and frictional heating, *NACA TN* 3458, 38 pp., July 1955.

The analysis represents a continuation of a detailed theoretical study by the author of the problem of steady-state fully-developed vertical laminar flow of a viscous heat-conducting fluid between two vertical plates. Included in the treatment are effects of a vertical body force and pressure gradient acting upon the fluid (forced and natural convection) as well as the effect of uniformly distributed internal heat sources. A fourth-order ordinary differential equation for the velocity is obtained which becomes linear if viscous heating within the fluid is neglected. In addition to solving analytically the approximate linear equation, numerical solutions of the exact nonlinear equation were obtained by means of an electronic computer. The solutions for the velocity and temperature distributions are given for the following two sets of boundary conditions: (1) temperatures on both walls are specified to decrease at the same rate linearly with increasing height (heating from below); (2) both walls are insulated.

The results show that there are a series of critical Rayleigh numbers which divide different flow regimes. In general the solutions are flows which circulate in vertical columns. Including distributed heat sources may alter the magnitude and sign of the velocity and temperature distributions; however it has no effect upon the critical Rayleigh numbers. Exact solutions, including viscous heating, are essentially identical to the approximate solutions except very near the critical Rayleigh numbers and for large values of the frictional heating parameter. It is interesting to note that two distinct exact solutions are obtained for each set of boundary conditions, and there is no obvious way to eliminate one in the regions of critical Rayleigh numbers.

F. Williams, USA

1005. Hottel, H. C., and Cohen, E. S., Radiant heat exchange in a gas-filled enclosure, ASME-AIChE Heat Trans. Conf., University Park, Pa., 1957. Pap. 57-HT-23, 36 pp.

A method is presented for calculating the temperature and heat transfer in a furnace, taking radiation exchange into account. The system is divided into surface zones and gas zones, sufficiently many to give the desired accuracy. Using available direct-exchange factors, the net-exchange factors for any zone pair can be computed, allowing for interaction with all other zones. The simultaneous solution of the resulting set of energy balances yields the desired distributions of temperature and heat flux,

H. D. Block, USA

1006. Keck, J., Kivel, B., and Wentink, T., Jr., Emissivity of high temperature air, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 279–294.

Spectral measurements, made in a shock tube, of radiation from air at temperatures between 5000 K and 9000 K are presented, together with a theoretical explanation of the results obtained. Discrepancies and regimes where present knowledge is inadequate are discussed. A. Whillier, S. Africa

1007. Bridgers, F. H., Paxton, D. D., and Haines, R. W., Solar heat for a building, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-26, 3 pp.

An Albuquerque, N. M., solar-heated building having a combination 7½-ton heat pump—750 sq ft solar collector—6000 gal (water) heat storage system is briefly described. Several operating difficulties that should be noted by others contemplating similar designs are mentioned, including corrosion of the integral tube-plate, aluminum radiation-absorbing panels due to residual flux, damage to piping due to freezing at night, and accumulation of air in the system. The experiment represents a bold venture into solar heating, and will yield valuable operating experience. The system is not intended to be economically competitive with conventional heating systems.

A. Whillier, S. Africa

1008. Birkebak, R. C., and Hartnett, J. P., Measurements of the total absorptivity for solar radiation of several engineering materials, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-27, 6 pp.

Values are presented of the total solar absorptivity of several porous materials presently being considered for transpiration cooling of high-speed vehicles, together with values for magnesium

oxide and for aluminum alloy with several degrees of polish. To specify the porous surfaces, photomicrographs and a chemical analysis are presented. The two experimental methods used in the measurements of the absorptivity values are described. One is a comparison technique and the other an integrating radiometer method. The results, and the experimental techniques, can be recommended. A. Whillier, S. Africa

1009. Priem, R. J., Borman, G. L., El Wakil, M. M., Uyehara, O. A., and Myers, P. S., Experimental and calculated histories of vaporizing fuel drops, *NACA TN* 3988, 36 pp. + 19 figs., Aug. 1957.

Paper presents results of a theoretical and experimental investigation of the vaporization of fuel drops in heated air under atmospheric pressure. First, an experimental investigation of the temperature and mass histories of single drops, with emphasis on small drops down to 500 microns, was made. Second, a comparison of experimental with calculated temperature and mass histories was made. Third, the time taken by a drop vaporizing in high-temperature air to form a mixture of fuel vapor and air at combustible strength in the film of the drop and at the self-ignition temperature is calculated. In addition, the vaporization of fuel drops in a spray under conditions where one drop influences another is investigated theoretically.

Main results: (1) An appreciable portion of the drop, up to 50% and more, may be vaporized during the "heating-up" period; (2) calculated and experimental times to reach the same percentage vaporized differed by 20%, with the computed values usually smaller; (3) computed ignition delay of single drops increases rapidly with decreased fuel volatility and decreased air temperature, and is relatively insensitive to variations in total pressure; (4) interaction between vaporizing drops in a spray cools the air, approaching the adiabatic equilibrium temperature.

Three appendices discuss: (A) Theory of drop vaporization in hot air stream. (B) Theory of self-ignition of single drop in hot air. (C) Adiabatic saturation in sprays.

K. J. DeJuhasz, Germany

1010. Benson, G. W., and Brisebois, R. J., Evaporation of fuel sprays II-Experimental work, *Nat. aero. Establish. Canad., Rep.* LR-182, 23 pp., Nov. 1956.

A new technique for measuring the rate of evaporation of a spray has been developed, based on the cooling produced when a spray evaporates adiabatically. Results obtained are consistent with theoretical treatment of Benson [AMR **10**, Rev. 3814]. The apparatus can be modified to give psychrometric data from which it is possible to calculate diffusion coefficients of vapors in air. Equipment comprises rotameters for liquid and for air, heat exchangers for liquid and for air, spray nozzle (Monarch Nozzle Series "R" with 30-deg cone angle and flow number 0.60), thermostat, and thermistor (Western Electric 6014 B). The experimental liquid was xylene, for which the psychrometric constants are given for a velocity range of zero to 260 cm/sec.

K. J. De Juhasz, Germany

1011. Howe, E. D., Vacuum flash distillation of sea water, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-92, 18 pp. + 1 table + 6 figs.

Author presents preliminary experimental results, together with theoretical calculations, on an LTD (Low Temperature Difference) plant for obtaining fresh water from sea water. Hot water at 85 to 110 F is introduced into an evacuated chamber (about 1 in. mercury pressure), and cold water at 50 to 70 F is used for condensation of the resulting vapor. A turbine may profitably be included in the system for generation of power if the temperature difference is greater than about 30 F. Air in the system was found to seriously impair the performance of the condenser, while special precautions were needed to reduce carry-over of liquid bubbles. Economic factors are not discussed, but outlook is encouraging.

A. Whillier, S. Africa

1012. Rose, H. E., and Barnacle, H. E., Flow of suspensions of non-cohesive spherical particles in pipes. Parts I, II, *Engineer, Lond.* **203,** 5290, 898–900, June 1957; **203,** 5291, 939–941, June 1957.

The pressure drop along a pipeline conveying suspensions of solid particles in air was experimentally determined. The total pressure change was analyzed as the sum of (a) pressure drop due to fluid flow alone, (b) pressure change due to the hydrostatic weight of the suspension, and (c) an additional pressure change due to the presence of the particles. The pressure change (c) was found to be independent of the inclination of the pipe and of the ratio of the particle diameter to pipe diameter. The pressure change (c) was found to be directly proportional to the mass-flow-rate ratio and to the square root of the density ratio. In addition, the pressure change (c) was found to be a function of the Reynolds number in the pipe.

Reviewer considers this study to be an example of logical, systematic, experimental investigation.

M. R. Carstens, USA

1013. Bailey, D. L., Description of the spray rig used to study icing on helicopters in flight, *Nat. aero. Establ. Canad.* LR-186, 7 pp. + 7 figs., Jan. 1957.

1014. Sahlberg, P. H., Temperature fields on one, two and multipass crossflow heat exchangers (in German), *Medd. Varmestromsgruppen* no. 3, 8–32, 6 figs., Feb. 1957.

Calculations are presented for the temperature conditions and performance of crossflow heat exchangers with one or several passes of the two fluids. For simple crossflow, a series is presented which expresses the main temperature difference between the two fluids and which converges better than the series originally reported by W. Nusselt. The results obtained are presented in tables and figures, and the terminal effectiveness is calculated for the special condition that the product of mass flow m times specific heat c is the same for both fluids. Eight types of multiple-pass heat-exchangers with and without mixing of the fluids between the various sections are then investigated, assuming mc to have the same value for both fluids. It is demonstrated that solutions to the partial differential equations distributing the heat exchange can be obtained by coordinate transformation and superposition of appropriate solutions available for the simple crossflow exchanger. Results are tabulated and compared in figures. E. R. G. Eckert, USA

***Anniversary volume dedicated to Professor Matts Backstrom—65th Birthday,* Kyltekn. Tidskr. no. 3, June 1957.**

1015. Ax, B., Swedish design and construction of refrigerator compressors (in Swedish), 76–80.

1016. Kropp, G. E., Household refrigerator compressors—Swedish design as early as 1912 (in Swedish), 81–82.

1017. Jung, I., Technology and economics for a turbine driven boat (in Swedish), 83–92.

1018. Andersen, S. A., Backstrom and Trouton (in Swedish), 93–96.

1019. Loffler, H.-J., Miscibility of synthetic oils with refrigeration fluids (in German), 97–100.

1020. Thorwid, C., Ammonia as opposed to Freon-12 and Freon-22 as refrigeration fluid (in Swedish), 101–102.

1021. Hagbers, S., and Persson, P.-O., Heat transfer analogy of an operative human body refrigeration (in Swedish), 103–107.

1022. Brandin, T., A new equation of state (in Swedish), 108–114.

1023. Lundvik, B., Deterioration of performance of Freon condenser due to presence of noncondensing gases (in Swedish), 115–118.

1024. Emblik, E., A note on air-cooled condensers (in Swedish), 119–120.

1025. Watzinger, A., Heat transfer from coolers by radiation (in Swedish), 121–123.

1026. Worsoe-Schmidt, P., Heat transfer due to combined free and forced convection in a cylindrical tube (in Danish), 124–128.

1027. Pierre, B., Heat transfer in boiling refrigerator fluids in a horizontal tube (in Swedish), 129–137.

1028. Sahlberg, P.-H., Temperature fields in a two and multipass cross-flow exchanger (in German), p. 128.

1029. Linde, J. O., Thermodynamic conditions at extreme low temperatures (in Swedish), 138–141.

1030. Bosnjakovic, F., Transfer phenomena in stream-air mixture (in German), 142–146.

1031. Kayan, C. F., Further developments in resistance-concept application to heat-power-process systems (in English), 147–151.

1032. Ahlqvist, D., and Nilsson, O., Comments on insulation of household refrigeration (in Swedish), 152–155.

1033. Tenelius, F., Heat loss through walls in contact with earth (in Swedish), 156–158.

1034. Brown, G., Computers as an aid to solution of unsteady-state temperature fields (in Swedish), 159–162.

1035. Lorentzen, G., Some investigations on cooling of meat (in Norwegian), 165–173.

1036. Molnar, A., Importance of breathing of vegetable products from the view of refrigeration (in Swedish), 174–180.

Combustion

(See also Revs. 823, 901, 902, 909, 976, 1005, 1009, 1010)

1037. Bitondo, D., Thomas, N., and Perper, D., Ignition in transient flows, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 343–358.

The mechanism of the ignition of combustible gas mixtures in transient flow across hot surfaces was studied. Ignition on a hot plate was observed in the induced flow behind a weak shock wave. An ignition delay-time was observed by using a spark-schlieren technique with an electronic time-delay circuit. With free-stream flow rates of 200 fps and surface temperatures approximately 1000 C, ethylene-air mixtures ignited with shorter time delays than propane mixtures. Absolute values of ignition delays were larger than in steady-flow apparatus. Approximate calculations of the thermal boundary-layer profile and thickness agree with schlieren observations. It appears that the rate-controlling process is a combination of chemical reactions and diffusion into the hot boundary layer.

H. F. Calcote, USA

1038. Hartmann, I., and Nagy, J., Inflammability and explosibility of powders used in the plastics industry, *U. S. Bur. Mines, RI* 3751, 38 pp., May 1944.

Thorough study of subject was taken to serve as basis for safety code for prevention of dust explosions in the plastics industry, and to make safer the production and handling of plastics powders. Fifty-seven powder samples, comprising 31 resins, 15 molding compounds, 4 resin ingredients and 7 fillers were tested. Similarly to the metal powders reported in a previous investigation [see following review]. Factors investigated were: minimum ignition temperature and minimum ignition energy; relative inflammability with two different sources of ignition, minimum concentration required in a dispersion of dust in air to permit flame propagation; maximum pressure, and maximum rate of pressure rise; reduction of oxygen content of air necessary to prevent ignition; moisture absorption when exposed in a humid atmosphere. Test equipment and procedure are described.

Results are given in detailed tables and charts. Most powders are more sensitive to ignition by hot surfaces than by electric sparks. Several powders developed 60 psi maximum pressure, and 2500 psi/sec rate of pressure rise. Most violent explosions are produced at concentrations intermediate between the lower and upper explosive limits. Decrease in particle size results in decrease of ignition temperature of the dust cloud, in decrease of minimum explosive concentration, in decrease of minimum energy required for ignition, and, in general, in an increase in the maximum explosion pressure and rate of pressure rise. Ignition and flame propagation of dust clouds of all powders tested can be prevented within grinding mills, screens, and other closed equipment by using gas, or low oxygen concentration. Exposed to atmosphere of high humidity certain plastic powders absorb considerable moisture. Comparative explosibility data are given for fine aluminum and magnesium powders, coal dust, and corn starch.

It is emphasized that in the manufacture and handling of powdered products in the plastic industry the recommendations of safety code should be adhered to.

K. J. DeJuhasz, Germany

1039. Hartmann, I., Nagy, J., and Brown, H. R., Inflammability and explosibility of metal powders, *U. S. Bur. Mines, RI* 3722, 45 pp., Oct. 1943.

Thorough study of subject was done in the dust-explosion laboratory of the Experimental Coal Mine Section of the Bureau of Mines. Fifty-three powder samples, for military and industrial uses, comprising 14 different metals and 2 alloys were tested. Factors investigated were: minimum ignition temperature and minimum ignition energy; effect of two different sources of ignition; minimum concentration needed for ignition; effect of reduction of oxygen content, and of humidity; maximum pressure and rate of pressure rise; spectrographic analysis, sieve analysis. Test equipment is described; it is the same as that used for coal-dust explosion. Systematic designation of the powders used. Experimental results are given in detailed tabulations. The highest maximum pressure was measured as 72 psi, with a magnesium powder dust cloud, giving a rate of pressure rise of 5000 psi/sec.

The over-all findings indicate that powders of zirconium, magnesium and its alloys, aluminum, and titanium are the most hazardous regarding explosibility. Less hazardous are iron, manganese, zinc, silicon, tin, and antimony. Lowest inflammability and explosibility are for cadmium, copper, chromium, lead, and milled iron. But all of these powders are explosive under certain conditions. Regarding fire hazard, minimum ignition temperatures of quiescent layers of dusts are tabulated. Quiescent layers of zirconium, magnesium, and magnesium alloys burned vigorously in

carbon dioxide and nitrogen when heated sufficiently. In atmospheres of high humidity most powders gained weight up to 55%, which gain was partly retained when samples were dried. Comparisons with work of others on metal powders and carbonaceous dusts are given.

Present tests emphasize that production of powders by any method should be done in compliance with existing safety codes. Need for further tests and investigation is emphasized, and some still needed information is listed.

K. J. De Juhasz, Germany

1040. Stehling, K. R., and Freeland, J. L., A mechanical igniter for liquid rocket engines, *Jet Propulsion* **27**, 8 (part 1), p. 896, Aug. 1957.

1041. Campbell, J. A., Appraisal of the hazards of friction-spark ignition of aircraft crash fires, *NACA TN* 4024, 10 pp. + 6 figs., May 1957.

1042. Klein, G., A contribution to flame theory, *Phil. Trans. roy. Soc. Lond. (A)* **249**, 967, 389–415, Feb. 1957.

Author reviews briefly the equations of reacting gas mixture and their application to flames. A one-dimensional flame model is considered and a general method of solution is aimed at. The ideal flame with the reaction $A \rightleftarrows B$ is discussed in detail, taking diffusion into account. The method consists of two stages: (1) successive approximation to the solution of an integral equation [cf. AMR **8**, Revs. 1517, 1518, 3350; AMR **9**, Rev. 4098], corresponding to the case of zero energy flux; and (2) by a perturbation method, based on the "unperturbated" case (1). In a second part, the simple $A \rightleftarrows B$ flame is generalized in such a manner that one may treat, e.g., two simultaneous reactions, first assuming that one of these reactions is in equilibrium, and then attacking the complete problem by considering the reaction rate previously neglected as a perturbation.

As a step toward chain reactions, a flame with the two simultaneous reactions: $A \rightleftarrows B$, $A + B \rightleftarrows B + C$; or $A \rightleftarrows 2B$, $A + B \rightleftarrows B + C$ was considered. Some further remarks concern the possibility of applying the presented method of solution to real flames. It seems that the procedure gives quite reliable results, which may be compared with experimental evidence.

W. Jost, Germany

1043. Mondiez, A., Laws of chemical kinetics in combustion on a grill and on a chain stoker (in French), *Chaleur et Industrie* **38**, 383, 145–163, June 1957.

Author presents an attempt to solve mathematically problems inherent in the use of solid fuels in conventional type of coal-heated power stations, with particular attention given to grill and chain stokers. Relations between variables governing the working of a chain stoker are considered and their application in normal stoke hole efficiency problems is discussed.

R. Delbourgo, France

1044. Holliday, D. K., and Thring, M. W., The radiation from flames in a small-scale oil-fired furnace, *J. Inst. Fuel* **30**, 194, 127–136, Mar. 1957.

Authors' aim is to determine whether combustion phenomena, and particularly radiation from flames, can be reproduced in small furnaces. He used an oil-fired furnace designed for quick equilibrium, for 4-ft flame fed at constant calorific input of 2.75 therms/hr, with 120% stoichiometric mixture and using atomizing air to give equal jet momentum. Water-cooled doors were arranged to give sliding aperture of 2-in.^{2} opening at many points along furnace walls. Fourteen different flame positions were studied for 14 different fuels to show range of $R = C/H$ weight ratio and boiling points of fuels. Velocity was determined from water-cooled Pitot tube; temperature from water-cooled suction pyrometer using Pt-Pt-13% Rd. thermocouple; filter-type soot probe also was water-cooled. Radiation was measured along furnace using radiation pyrometer with Kipps-type thermopile. Split thermopile received part of radiation from flame with furnace wall as background, rest received radiation from flame with water-cooled doors as background.

An empirical equation was developed relating flame radiation emissivity and boiling point of fuel at NTP: $R = C/H$ by wt; T = boiling point (°C) $E_{T_{AV.}} = (0.2821) \ln [(R - 5)/4] + 0.002(T - 200) + 0.484$; also: relation for emissivity and C particle concentrated along flame axis: $E_T = [1 - e^{(-.0025\, CL)}]$ where L is flame width in cm, C is carbon-soot concentration in mg/litre, NTP. Similar results were derived from data taken at other furnaces at Delft and at Ijmuiden. Linear dimensions of this furnace are 1/5 those of Ijmuiden. There is a typographical error in 3rd conclusion: "n" should read "e" in Eq. Greater soot concentration found in smaller furnaces suggests that same amount of soot is formed in all cases, but more soot is destroyed in longer flames of larger furnaces.

Reviewer considers this a distinct contribution to the literature of combustion. Paper shows evidence of great care in planning, instrumentation, and analysis of data. The correlations with work at Delft and Ijmuiden are very interesting.

J. H. Potter, USA

1045. Thring, M. W., Some recent developments in the physics of fuel combustion, *Brit. J. appl. Phys.* **8**, 3, 89–97, Mar. 1957.

Author cites many-fold difference between heat-release rates attained in experimental well-stirred combustion chambers and rates common to industrial practice, to emphasize point that performance of practical systems is limited not by chemical processes but by physical ones of mixing and heat loss from the flame. Microscale mixing, i.e. of individual fuel drops or particles with air, varies with square of initial particle size, indicating value of fine atomization. Macroscale mixing of air and fuel is predictable from performance of isothermal jet-mixing models, a special model generally being required for each problem. Three successfully modeled systems are: (1) high velocity fuel jet, (2) large preheated gaseous fuel jet, and (3) low Reynolds number heating flue.

The much more difficult problem of predicting radiant heat-transfer rates in furnace enclosures is also being attacked, with necessarily drastic simplifying assumptions but with results that do enable fair prediction of the effects on flame temperature and heat-transfer rate of changes in operating variables.

P. Jensen, USA

1046. Bailey, J. J., A type of flame-excited oscillation, *J. appl. Mech.* **24**, 3, 333–339, Sept. 1957.

A theoretical study of the inception of standing waves in the familiar Rijke tube. Author uses open-end tube containing a flat brass screen flame holder. Combustible gas is supplied through a large plenum chamber to reduce end effects. Frequency of the initially-heard pure notes was measured for various configurations. Oscillations were observed with cellular flames over a narrow composition and velocity range, and with "flat" flames over a much wider range corresponding to relatively close attachment of the flame to the holder. Author presents linear theory, including damping effects, for "flat" flame singing based on Rayleigh's criterion.

Reviewer believes this is not a newly observed phenomenon as the author contends. For example, see Rosenberg's "Experimentierbuch," Vol. I, p. 303, Alfred Holder, Wein & Leipzig, 1908, where experiments of M. Rosenfeld are described using an almost identical apparatus. At least one rough theoretical analysis of this phenomenon has been made recently [A. A. Putnam and William R. Dennis, Organpipe oscillations in a flame-filled tube, Fourth Symposium on Combustion, Williams and Wilkins, Baltimore,

Md., 1953, pp. 566–575. However, author does present a rather complete theoretical analysis which predicts with good certainty the harmonic which should appear first and its frequency for a wide range of tube configurations.

R. A. Strehlow, USA

1047. Bailey, J. J., A type of flame-excited oscillation in a tube, ASME Summer Conf., Berkeley, Calif., June 1957. Pap. 57—APM-26, 7 pp.

Two types of combustion-driven oscillations produced by a flame burning above a grid in a tube open at both ends are reported. In one, the flame assumes a cellular shape [see AMR **9**, Rev. 930]. In the other, which is discussed in detail and explained theoretically in this paper, the flame has a flat character. [See AMR **6**, Rev. 1721; **7**, Rev. 2664; **9**, Rev. 929.] The observed frequencies are found to be natural frequencies of tube, when the effect of the increased temperature in the hot region is accounted for. For a constant position of the grid from the downstream end of the tube, the frequency of oscillation was found to decrease with increasing tube length, as expected, and then, at some point, jump to a high frequency and higher mode, decrease again with increasing tube length, jump again, and so on. However, at some high mode number, eight is the example given, the order of occurrence changed to 8, 9, 8, 10, 9, 11, 10, and so forth. In every instance, however, the flame in author's equipment was between one quarter and one half wave length from the downstream end of the tube. It may be noted that this last observation was not true in all instances in the data on grid-held flames reported by Blackshear [AMR **6**, Rev. 1721; **7**, Rev. 2664].

The accompanying theoretical explanation is based on the assumption that the instantaneous burning velocity of the flame is equal to an average burning velocity plus a perturbation proportional to the distance of the flame from its average position. It is also assumed that the major loss of acoustical energy is in radiation from the tube ends. With these assumptions, author derives a relation explaining all his observations except the unusual order of modes observed at longer lengths of combustion tube. He indicates a test on a radically changed piece of equipment showed the expectant order; he deduces, therefore, that the unusual order is an effect of apparatus not accounted for in the theory, probably in the damping term.

This reviewer feels that instance can be encountered in similar equipment when the assumption relative to the change in instantaneous burning velocity with flame position would have to be modified by a distributed time lag [see H. J. Merk, *Appl. sci. Res.* (*A*) **6**, p. 402, 1957] to account for a strong effect of heat transfer from the flame to the grid. As an extreme example, this flame phenomenon might become in detail much like that of the classical Rijke gauze tone, which it resembles in general in the case discussed. However, in the system considered, this additional effect was apparently secondary, and its inclusion would only have complicated the result.

A. A. Putnam, USA

1048. Schoppe, F., On mixing mechanisms in gas-fired combustion chambers (in German), *VDI-Forschungsheft* 456, 22, 39 pp., 1956.

While adequate theories exist for the design of compressors and turbines, the design of a combustion chamber of a gas turbine plant is still very much empirical. Paper presents a theoretical and experimental attempt to rectify the position and to assess the significance of some of the parameters which determine the performance of a chamber.

In order to exclude the characteristics of the fuel and its method of injection into the chamber, attention has been focused on one gaseous fuel only. On the assumption, supported by experiment, that the mixing of the fuel and air occupies a much longer path than that required for the actual combustion, author develops theories for laminar diffusion mixing and turbulent mixing, and deduces that such mixing processes effectively determine the size of any chamber. He shows that laminar mixing is of little technical importance since it yields unacceptably low energy releases per unit volume. Using theories of free turbulence, author then derives simple relations for flame length and rate-of-energy release per unit volume for a few simple geometric arrangements of air and fuel supply, and he also predicts a scale effect.

Although most of the experimental arrangements are not of such simple configuration as those analyzed theoretically, results lend support to the most important theoretical predictions. Interesting is the theoretical result, supported by one scale-effect experiment, that for geometrically similar chambers the rate-of-energy release per unit volume is inversely proportional to the linear dimension of the chamber. For this reason, as well as for keeping the pressure loss low, author concludes that several small chambers are to be preferred to a single large chamber.

Y. R. Mayhew, England

1049. Olson, W. T., Combustion for aircraft engines, Fifth International Conf., Los Angeles, Calif., June 20–23, 1955, 449–481; New York, Inst. of Aeronautical Sciences, Inc.

A comprehensive review of the influence of basic combustion characteristics on ramjet and turbine-engine performance. Includes effect of such items as ignition delay, quenching distance, bunsen burner blow-off velocities and fluid mechanics, mass transfer and heat transfer on combustion efficiency, blow-out limits, re-light characteristics, and pressure drop in typical configurations.

E. S. Starkman, USA

1050. Priem, R. J., Propellant vaporization as a criterion for rocket engine design; calculations of chamber length to vaporize a single *n*-heptane drop, *NACA TN* 3985, 15 pp. + 1 table + 10 figs., July 1957.

Calculations were made for *n*-heptane drops, using various drop sizes, injection velocities, final gas velocities, initial fuel temperatures, and chamber pressures, to show how these variables would affect the vaporization rate and the chamber lengths required to vaporize the drops. Calculations indicate that droplet vaporization may be the controlling process in the combustion zone. Results are correlated for ease in using them for design purposes. Results agree with experimental data obtained previously with liquid oxygen-heptane rocket.

Results: (1) Chamber length required for a given percentage of fuel vaporized increases with larger drop sizes and higher injection velocity; (2) chamber lengths required for a given percentage vaporized decrease with higher final gas velocity, higher chamber pressures, and higher initial temperatures; (3) calculated results agree with experimental results.

K. J. DeJuhasz, Germany

1051. Wood, B. J., Wise, H., and Rosser, W. A., Burning of a liquid droplet. IV. Combustion inhibition in a fuel-oxidizer system, *J. chem. Phys.* **27**, 3, 807–808, Sept. 1957.

Extinction of diffusion flame at forward stagnation point of ethanol sphere is brought about by adding chemical inhibitors to air stream. Results are qualitatively in accord with theories of Zeldovich [*NACA TM* 1296], the reviewer [Fourth Symposium and *Fuel* **33**, p. 253, 1954], and Lorell, Wise and Carr [*J. chem. Phys.* **25**, p. 325, 1956]. Quantitative comparison with relation between extinction condition and laminar flame speed, derived in first two references, is not made.

D. B. Spalding, England

1052. Wise, H., and Ablow, C.M., Burning of a liquid droplet. III. Conductive heat transfer within the condensed phase during combustion, *J. chem. Phys.* **27**, 2, 389–393, Aug. 1957.

Temperature distribution history of sphere with fixed surface temperature, and diameter shrinking at rate inversely proportional to diameter, is calculated theoretically. Results are relevant to

burning of liquid fuel droplet; in latter case, however, surface temperature rises with time and bears nonlinear relation to surface heat flux. Present paper represents useful first step; analysis of complete problem is needed before results can be accepted as representing droplet behavior.

D. B. Spalding, England

1053. Zaehringer, A. J., Solid propellant bibliography, *Jet Propulsion* **27,** 8 (part 1), 900–901, Aug. 1957.

Acoustics

(See also Revs. 1046, 1047)

1054. Lassiter, L. W., Turbulence in small air jets at exit velocities up to 705 feet per second, *J. appl. Mech.* **24,** 3, 349–354, Sept. 1957.

Turbulence characteristics of jet streams are significant with regard to the generation of jet noise. Author extends measurements of jet turbulence of Corrsin [*NACA Wartime Rep.* W-94, 1943] in the low-speed range to higher velocities. He gives an extensive study of intensity, longitudinal and radial scale as well as spectra of the turbulence in the whole interesting region of the stream.

Turbulence intensity is invariant with mean velocity only in the fully developed region of about 15 diameter downstream from the nozzle exit. Especially in the undisturbed region intensity decreases considerably with an increase of Reynolds number. This influence diminishes with the radial distance from the axis. The increase with axial distance happens in a different manner. Half a diameter from the axis, longitudinal and radial scale of turbulence were found to increase to about the square root of axial distance from the nozzle. The turbulence spectra in the center line consist of a sharply peaked band of frequencies near the nozzle exit and degenerate to a rather broad band with increasing axial distance.

N. Scholz, Germany

1055. Fradkina, E. M., and Shirokov, M. F., The noise of a rotating aircraft propeller during its forward movement in a medium, and movement of the medium in relationship to the sound receiver (in Russian) *Trudl NAI* no. 51, 5–14, 1955; *Ref. Zb. Mekh.* 1956, Rev. 5068.

Application of the theory of a delaying potential to the equation of acoustics in Lamb's form enables the following equations to be obtained for the sound pressure set up in the moving unlimited medium by a variable volume force

$$p = \frac{e^{i\omega t}}{4\pi} \int_{\Omega} (K_0 \operatorname{grad} f)\, dx\, dy\, dz,$$

$$f = \left[r'\left(1 - \frac{v}{c}\cos\vartheta\right)\right]^{-1} \exp\, -\frac{i\omega r}{c}$$

in which $K_0(x,y,z)$ is the amplitude value of the density which varies according to the harmonic law with angular velocity ω of the volume force, f is the function of the coordinates of the power wave at the moment t, c the velocity of sound, r' the distance from the imaginary sound source to the observer, v the speed of movement of the medium, and ϑ the angle between r and v.

The point source of this type is an acoustic dipole, the sound characteristic of which essentially depends upon v/c and the orientation K. The equations obtained make it possible (using L. Ya. Gutin's method, *Zh. tekhn. Fiz.* **6,** p. 899, 1936) to calculate the approximate value of the power radiation of the propeller. The sound field of the propeller in the moving medium cannot in principle be determined by means of its calculation for the case of a medium at rest, with subsequent introduction of corrections for aberration and the Doppler effect, since the presence of the flow velocity has a different effect on the radiation of dipoles which are equivalent to the thrust and resistance of rotation.

The presence of motion of the receiver relative to an immobile radiator influences the measurable characteristic of direction.

Examination is made of the case of aberration in simultaneous parallel motion of a source and a receiver. In the case of an identical velocity of motion, aberration of sound is absent, but intensity of sound varies as a result of the variation in the propagation speed of the sound energy.

E. Ya. Yudin, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

1056. Toulis, W. J., Acoustic refraction and scattering with compliant elements. I. Measurements in water, *J. acoust. Soc. Amer.* **29,** 9, 1021–1026, Sept. 1957.

The presence in a body of liquid of volume elements having a boundary of low impedance (for example, air bubbles) lowers the effective bulk modulus and hence sound velocity and characteristic impedance of the medium. Compliant elements can therefore be used to produce refraction and scattering of sound waves. Author presents experimental data obtained with compliant elements in the form of aluminum tubing with elliptically deformed cross sections. Arrays of parallel tubes were used.

These arrays can be used as acoustic lenses in the frequency region sufficiently far below the lowest natural frequency of the tubing to insure that the dispersion curve of the medium containing the compliant elements is relatively flat. When used as reflectors, the arrays produce good reflection efficiencies at frequencies for which the tube spacing is less than a half wave length.

M. C. Junger, USA

1057. Toulis, W. J., Acoustic refraction and scattering with compliant elements. II. Analysis, *J. acoust. Soc. Amer.* **29,** 9, 1027–1033, Sept. 1957.

Paper presents analysis of system whose experimental study is described in the preceding review. Analytical and experimental work seems generally in good agreement, except on one point: Theory predicts that the compliant elements will lower velocity of sound waves whose frequency is below the fundamental natural frequency of the compliant elements, and raise the velocity for frequencies above resonance. Latter effect is not borne out by author's experiments. As the velocity increase above resonance has been observed in water containing air bubbles [Silberman, title source **29,** 925–933, 1957], author's suggestion that discrepancy is due to neglect of coupling between compliant elements seems incorrect. Reviewer believes that discrepancy is due either to a flaw in the experimental method, or to neglect, in the analysis, of flexural effects in the axial direction of the tubes: In round tubes, these effects keep the wall stiffness-controlled even above ring resonance frequency.

M. C. Junger, USA

1058. Nisbet, J. S., and Brennan, J. N., Some secondary effects related to impact wave forms, *J. acoust. Soc. Amer.* **29,** 7, 837–841, July 1957.

Authors present first a comparison of the shock spectra of three acceleration pulses: exponential, one minus cosine, linear. Discussion involves differences between theoretical and practical shock spectra as obtained from a shock machine; discontinuities in acceleration, or time derivative of acceleration, can result in appreciable differences. Effects of shock-excited resonances in a machine are also discussed.

H. N. Abramson, USA

1059. Rich, T. A., Characteristics of airborne particles, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-56, 9 pp.

Author's summary at the beginning of the paper is well stated and could be used as a satisfactory abstract. For more detail, the following paragraph could be added:

Author discusses the mechanisms by which particles are formed in the atmosphere and the various theoretical relationships which

have been developed to define particle size and number. These properties of an aerosol system are also related to light transmission, diffusion, and electrical properties by various formulas. Fifteen references are cited. H. McKee, USA

1060. Havemann, H. A., and Bhaktavatsala, B. S., Experiments on a new type of dust separator for steady and pulsating flow, *J. Indian Inst. Sci.* **39,** 1, 23–51, Jan. 1957.

The study shows that cyclone dust separators with a flat bottom have a tendency of developing high vertical velocities near the axis which tend to move part of the deposited dust from the bottom to the discharge opening and out. It is shown that this effect can be reduced materially by placing a cone concentrically at the bottom pointing towards the top. The dust settles through openings between the cone and the cylindrical wall of the separator into a separate dust bunker. H. A. Einstein, USA

1061. Korenev, H. S., The theoretical bases of the processes of the cleaning of gas and air to remove dust particles in the layers of various packs (in Russian), (Gos. Soyuz. i.-i. avtomob. i avtomotor in-t. no. 72) Moscow, Mashgiz, 1954, 24 pp. + illus. 75 kob.; *Ref. Zb. Mekb.* 1956, Rev. 6074.

Processes are investigated dealing with the separation of dust particles when air is passed through the packs present in filters used in motors and tractors. Author is of the view that the process of removal of particles of dust from the gas consists of two stages. In the first stage the dust particles separate out, basically, under the action of forces of inertia, which develop as a consequence of multiple small revolutions of the flow in the pack layer. In the second stage of the gas cleansing, the active part is played, basically, by the impact of the dust particles on the surface of the solid or liquid bodies.

A suitable formula is deduced to calculate the coefficient of cleansing. A formula is given for the evaluation of the resistance of the pack in relation to its working time at given through-puts of air and the constructive parameters of the pack. Examples are given, utilizing the formulas cited in the article.

I. E. Idel'chik, USSR
Courtesy Referativnyi Zburnal
Translation, courtesy Ministry of Supply, England

1062. Ranz, W. E., and Wong, J. B., Impaction of dust and smoke particles on surface and body collectors, *Indust. Engng. Chem.* **44,** 1371–1381, June 1952.

Investigation of mechanism of collection of dust and smoke particles from the standpoint of fundamental study of impaction of aerosol particles on elementary collectors. The systems analyzed were rectangular and round aerosol jets impinging on flat plates (jet impactors and impingement separators) and cylindrical and spherical collectors placed in aerosol streams (fibrous filters and wet scrubbers). Theories of mechanisms were reviewed and extended, and an approximation method, involving dimensionless parameters, is proposed for determining the efficiency of impaction even in the most complicated situations. Experimental data were obtained for the inertial mechanism operating in the systems under study. Rates of collection of glycerol and sulfuric acid aerosol particles of nearly uniform size were measured by impaction on wires and spheres in streams moving at various velocities and by impingement on flat plates from jets of different sizes and velocities. Experimental results and theory were compared and applied to the analysis of practical problems.

The experimental equipment is described, comprising an aspirating system, filters, dryers, electron nucleus generator, humidifier, reheater and the jet impactor; with this the impaction efficiency of the jets, and the impaction of body collectors were determined, in particular, of cylindrical and of spherical collectors. The results are given in graphs. K. J. De Juhasz, Germany

1063. Philip, J. R., Transient fluid motions in saturated porous media, *Austr. J. Pbys.* **10,** 1, 43–53, Mar. 1957.

Author studies, by means of Stokes-Navier equations, the transition from rest to steady motion consequent to the sudden application of a potential gradient to an incompressible fluid contained in a porous medium. The time for the establishment of the steady motion is found to be proportional to the coefficient of permeability and inversely proportional to the kinematic viscosity, but it does not usually exceed a fraction of a second. Therefore the error involved in using Darcy's law, which neglects the transient phase, can be considered unimportant in practical cases.

Author demonstrates, however, that significant deviations from Darcy's law may occur when the applied potential gradient is periodic, even if the frequency of the system is as low as one cycle per minute. R. Jappelli, Italy

1064. Babalyan, G. A., The thermodynamic analysis of the process of mutual expulsion of liquids from porous media (in Russian), *Trudl Neft. ekspeditsii Akad. Nauk Az. SSR* **2,** 97–110, 1955; *Ref. Zb. Mekb.* 1956, Rev. 5323

An examination is made of the variation in the surface energy of the petroleum-water-stratum system when one liquid is expelled by another from a porous medium. It was shown that this analysis may be used without special reservations only for the case of the presence of equilibrium states of the system. The system examined is always a nonequilibrium one. Therefore the results of the analysis are conditional, and should be used with care.

Several particular cases of the expulsion of petroleum by water, and conversely, are examined. E. M. Minskii, USSR
Courtesy Referativnyi Zburnal
Translation, courtesy Ministry of Supply, England

1065. Averyanov, S. F., The influence of the standing depth of ground waters on filtration from channels (in Russian), *Gidrotekh. Melior.* no. 4, 59–61, 1955; *Ref. Zb. Mekb.* 1956, Rev. 5298.

A short communication regarding the approximate determination of steady filtration losses from a system of equidistant parallel channels of the same cross section in homogeneous soil with deep location of a water obstructor ($T = \infty$).

The value of the filtration losses, taking into account the influence of the standing depth of soil waters, is determined from the formula

$$Q_\phi = \alpha\,\bar{Q}_\phi \;(0 \leqslant \alpha \leqslant 1)$$

where $\bar{Q}_\phi$ is the maximum value of steady filtration losses from long acting channels and α is the coefficient which allows for the supporting influence of soil waters.

Author gives a transcendental equation and a graph which make it possible to determine the coefficient α to two decimal places. For the maximum value of the losses the following formula is given

$$\bar{Q}_\phi = k_1\left(1 + 0.5\,\frac{H_k}{B}\right)(B + 2b_0)\left[\frac{m^3}{\text{days}}\text{ per lin. m}\right]$$

where B is the width of the channel according to the reduction of water; b_0 the depth of the water in it, in m; and H_k is the maximum height of the capillary rise in m; k is the coefficient of capillary penetration for full moisture content, but taking into account the compressed air. An example is examined.

P. F. Fil'chakov, USSR
Courtesy Referativnyi Zburnal
Translation, courtesy Ministry of Supply, England

1066. Kaplinskii, M. I., The problem of filtration from channels in the presence of a flow of ground waters under a channel (in Russian), *Izv. Kuibyisbevsk., inzb.-melior. in-ta* **2,** 149–154, 1955; *Ref. Zb. Mekb.* 1956, Rev. 5299.

Results are given of experimental work on estimating the influence of the flow of soil waters or of an inclined water obstructor

on the value of the filtration discharge from a channel. Calculation of the discharges is made by very approximate hydraulic formulas. The tests were made in a soil trough 30 cm in height, and author did not consider the capillary influence, which can considerably affect the value of the filtration discharge.

Author's basic conclusion that losses from channels are independent of the deflection of the flow of soil waters, and also of the deflection of the water obstructor, is without foundation.

It should be mentioned that there is a strict hydromechanical solution of this problem [S. N. Numerov, *Izv. Vses. n.-i in-ta gidrotekhn.* **46**, 1951]. A. R. Shkirich, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

1067. Danilov, V. L., The problem of determining the pressure field in the case of the given law of contraction of a petroleum-bearing contour (in Russian), *Izv. Kazansk. fil. Akad. Nauk SSSR, Ser. Fiz. Mat. i Tekhn.* no. 6, 53-62, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5310.

The problem of determining the pressure field in the petroleum region of a seam for the known law of displacement of the petroleum-bearing contour is reduced to the Newman problem. A similar problem for the water region of the seam leads to the Cauchy problem for the Laplace equation; in connection with this the error of the problem examined is noted. Under some additional conditions imposed on the contraction law it is possible to have the existence and singularity of the solution of the problem of pressure distribution in the water section.

As an example an examination is made of the problem of the displacement of the circular petroleum-bearing contour which is contracted to the center of the contour. Inside the circular petroleum-bearing region there are *n* fixed crevices which act with given discharges. The solution of the particular problem comes to the fact that, with a given contraction law of the contour in the water section of the seam, there should be mobile characteristics of the seam of the type of "floating crevices". From this the conclusion is drawn that the problem of controlling the displacement of the petroleum-bearing contour should be solved approximately by assuming the condition of immobility of the crevices in the water zone. B. P. Pilatovskii, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

1068. Oroveanu, T., and Pascal, H., Plane radial steady flow of liquid and gas mixture in a porous medium (in Rumanian), *Studii si Cercetari Mecan. appl.* **7**, 2, 387-391, 1956.

Steady flow of liquid and gas mixture toward a well situated at center of circular bearing is considered, flow being assumed plane radial. Using results of previous study [*Acad. Republ. pop. Rom. Comun.* **4**, no. 9, 1955], authors establish formulas giving liquid and gas discharge under different given pressure conditions.

V. N. Constantinescu, Rumania

Ballistics, Detonics (Explosions)

(See Revs. 752, 852, 919, 1038, 1039, 1049)

Soil Mechanics, Seepage

(See Revs. 837, 1063, 1066, 1068)

Micromeritics

(See Revs. 781, 911, 1012)

Geophysics, Meteorology, Oceanography

(See also Revs. 840, 924, 959)

1069. Miche, R., Oceanic wave trains. Parts I, II, *Rev. gén. Hyd.* no. 74, 64-74, Sept.-Oct. 1956; no. 75, 141-153, Nov.-Dec. 1956.

In the first part of this report, simple asymptotic approximations to the general solutions of problems relating to ocean waves are developed. The usual assumptions of an ideal incompressible infinite fluid moving irrotationally are made, and the curvature and rotation of the earth are neglected. Nevertheless, these simplifications yield results which apparently agree quite well with observed data.

The second part commences with a resumé of methods at present used for forecasting. Those considered are (1) the semiempirical method of Sverdrup-Munk-Bretschneider, (2) the Pierson-Newmann method based on more accurate theoretical analysis, and (3) intermediate method suggested by Miche. Comparison is then made by consideration of an average disturbance in the North Atlantic. Finally, the possible advantages and limitations of the methods are discussed in detail. G. Power, England

1070. Shufflebarger, C. C., Payne, C. B., and Cohen, G. L., A correlation of results of a flight investigation with results of an analytical study of effects of wing flexibility on wing strains due to gusts, *NACA TN* 4071, 27 pp. + 1 table + 12 figs., Aug. 1957.

An analytical study of the effects of wing flexibility on wing strains due to gusts is made for four spanwise stations of a four-engine bomber airplane, and the results correlated with results of a previous flight investigation. The measured bending-strain amplification factors due to wing flexibility (ratio of strain for the flexible airplane to strain for the "rigid" airplane) at a station near the wing root were 1.09 when based on the ratio of root-mean-square values and approximately 1.19 when based on the ratio of strains obtained from distributions of strain peaks. The amplification factors decreased with each successive outboard station and then increased slightly at the tip station. When the airplane was considered to have three degrees of freedom (vertical motion and wing bending in the first and second symmetric bending modes), calculated amplification factors were in reasonable agreement with the measured results. A. M. Kuethe, USA

1071. Frenkiel, J., and Zacks, S., Wind-produced energy and its relation to wind regime, *Bull. Res. Counc. Israel* **6A**, 3/4, 189-214, Apr.-July 1957.

From known wind regime and assumed characteristics of two types of aerogenerators, authors describe three methods of estimating wind-produced energy, i.e., (a) based on the known frequency distribution of hourly mean wind speeds, (b) based on the formula of the power in the wind as a function of cumulative frequency, and (c) graphical method; numerical data applying to the typical wind-power sites in Israel illustrate the methods.

The relationship of the wind-produced energy (1) to the mean wind speed and (2) to the total energy in the wind is studied, and it is found that for a specific wind-power site there exists a clear relationship between two quantities in the case of (1) and (2), but a general relation embracing all the four wind-power sites in this semi-arid land can not be found. For practical purposes, mean wind speed rather than energy in the wind is a reliable yardstick of the energy to be extracted by the wind machine.

A book written by Golding [AMR **10**, Rev. 594] is frequently mentioned. Some British writer does not value it highly [*Quart. J. roy. meteor. Soc.* **82**, 547-548, Oct. 1956], but reviewer believes it is a unique work, although not highly scientific.

H. Arakawa, Japan

1072. Romov, A. I., On the variations in whirlwinds and the circulation of velocity in the atmosphere (in Russian), *Trudi. Ukr. n.-i gidrometeorol. in-ta* no. 4, 18–28, 1955; *Ref. Zh. Mekh.* 1956, Rev. 6026.

An examination is made of certain conformities to rule in the changes of circulation and whirlwind velocities when atmospheric movements are present. The known component in the formula for individual changes of the velocity circulation, described as due to Coriolis force, is changed to another, and not customary, view (in place of the integral presentation based on the theorem of mean value, a differential presentation of this term is introduced). In this view the formula for the change in circulation is wholly analogous to Friedman's equation for the change of whirlwind velocity. In applying the equation for whirlwinds (or the formula for change circulation) to the analysis of the conditions governing the formation of water spouts, it is essential to take account of the components generally disregarded, namely, terms dependent on the vertical components of the Coriolis force and particularly on the vertical gradient of the wind. Analysis of the last term, representing in itself the value of the vectoral product of the vertical gradient of the wind vector and the horizontal gradient of the vertical velocity, shows, in correspondence with the observed known mechanisms, that water spouts with cyclonic rotation should be formed on the right hand side of the frontal thunder cloud, where most probably there has been intensification of the cyclonic whirlwind. L. S. Gandin, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

1073. Pinus, N. Z., On the atmospheric turbulence causing aeroplane bumping (in Russian), *Meteorol. i gidrologiya* no. 2, 52–57, 1955; *Ref. Zh. Mekh.* 1956, Rev. 6031.

Some results are stated on the theoretical and experimental investigations, carried out in the U.S.S.R. and abroad, on title problem. Turbulence causing bumping is presented as an interchange in space of convecting, ascending, and descending currents of air, acting at short intervals of time. As a measure of disturbance, the horizontal extension of a portion of the atmosphere is taken in which the vertical movements retain their direction. The horizontal extension of the disturbed layers varies from a few kilometers to tens and sometimes hundreds of kilometers; the most characteristic extension is 80–100 km. The vertical extension of these layers in the lower half of the troposphere in 76% of the cases does not exceed 800 m, in the upper half of the troposphere it does not exceed 1000 m, on average. In general, however, the probability of bumping in the upper troposphere is reckoned around 10%. In these conditions, flights at high altitudes with overloads at $\Delta n = \pm 2g$ are extremely unpleasant, and at $\Delta n > 0.5g$ give rise to serious difficulties in pilotage. The probability of moderate and strong bumping is likely to be in the atmospheric layer up to 1 to 2 km from the ground, then it decreases with increase in height and again increases somewhat in the upper troposphere. Turbulence, producing bumping, is more likely to be met with in spaces with a developed convectional activity, in a zone of cold fronts, in the rear ends of cyclones, and also under layers of inversion point temperature. It is most likely to be encountered in that part of altitudinal frontal zone where convergences of air currents are observable and also when nearer to the region of low pressure.

In the upper troposphere, bumping ordinarily is met with in the layer 1–2 km below the tropopause, especially when tilt is considerable (of the order 1/80). I. G. Pchelko, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

1074. Yoshitake, M., Propagation of long waves on a rotating globe, *Geophys. Mag., Tokyo* **27,** 4, 487–506, Dec. 1956.

Author develops equations for conservation of vorticity about the local vertical on a spherical earth, retaining terms of the order of the earth's curvature along with those of the order of $\partial/\partial x$ and $\partial/\partial y$. The variation of df/dy is also taken into account, where f is the Coriolis parameter.

Disagreement with author is possible as to what conditions on sphere "correspond" to Rossby's solution for the plane; in any event, differences of speed of propagation are not important for (angular) wave numbers greater than three. Solutions in terms of associated Legendre functions are developed, of greater generality than that of Haurwitz, but of questionable value in the absence of an adequate discussion of boundary conditions on the sphere. M. Wurtele, USA

1075. Chandrasekhar, S., The thermal instability of a rotating fluid sphere heated within, *Phil. Mag.* (8) **2,** 19, 845–858, July 1957.

Consideration is given to the thermal instability of an incompressible rotating fluid sphere heated by a uniform distribution of internal heat sources. The equations governing the state of marginal instability are derived for the case when the motions and the associated perturbations have symmetry about the axis of rotation. The eigenvalue problem is solved for a slightly modified set of boundary conditions. The solution obtained, nevertheless, does determine the general nature of the relation between the lowest Rayleigh number for the onset of instability and the Taylor number ($T = 4\,\Omega^2 R^4/\nu^2$). S. Ostrach, USA

1076. Murakami, T., On the seasonal variation of mean vertical velocity and atmospheric heat-sources over the Far East from spring to summer, *Pap. Meteor. Geophys.* **7,** 4, 358–376, Jan. 1957.

Using the monthly normal data given in the Normal Weather Charts published by the U. S. Weather Bureau, mean vertical motion and heat supply over the Far Eastern Area have been computed. In June it was detected that there is a marked area of descending motion over the southern part of the Sea of Okhotsk, whose maximum speed attains about $10 \cdot (\text{mb} \cdot 12\ \text{hr}^{-1})$ at 850-mb level. Meantime the existence was also detected of a cooling area over the southern part of the Sea of Okhotsk, whose maximum cooling attains about $0.2\ (\text{cal} \cdot \text{gr}^{-1} \cdot 12\ \text{hr}^{-1})$. This elaborate work shows the dynamical significance of the well-known existing theory on Bai-u, the rainy season of Japan. H. Arakawa, Japan

Lubrication; Bearings; Wear

(See Revs. 762, 780)

Books Received for Review

BLENCH, T., Regime behaviour of canals and rivers, London, Butterworths Scientific Publications, 1957, xii + 138 pp.

CHANDRASEKHAR, S., An introduction to the study of stellar structure, New York, Dover Publications, 1957, 509 pp. (paperbound)

CHURCH, A. H., Mechanical vibrations, New York, John Wiley & Sons, Inc., 1957, xii + 275 pp. $6.75.

GATEWOOD, B. E., Thermal stresses, New York, McGraw-Hill, 1957, xv + 232 pp. $7.50.

Getriebe-Kupplungen-Antriebselemente, Braunschweig, Freidr. Vieweg & Sohn, 1957, 293 pp. DM 28,80.

HAM, C. W., CRANE, E. J., and ROGERS, W. L., fourth edition, New York, McGraw-Hill, 1958, xii + 509 pp. $8.50.

History of German guided missiles development, Agardograph 20, Brunswick, Germany, Wissenschaftliche Gesellschaft fur Luftfahrt, viii + 420 pp. $7.50.

JAKOB, M., Heat transfer, II, New York, John Wiley & Sons, Inc., xxxii + 652 pp.

KINNEY, J. S., Indeterminate structural analysis, Reading, Massachusetts, Addison-Wesley Publishing Co., 1957, xiii + 655 pp. $9.50.

KUETHE, A. M., edited by, Proceedings of the fifth midwestern conference on fluid mechanics, held at the University of Michigan, April 1957, viii + 388 pp. $3.00.

KUETHE, A. M., edited by, Proceedings of the third midwestern conference on solid mechanics, held at the University of Michigan, April 1957, vi + 250 pp. $5.50.

LELIAVSKY, S., An introduction to fluvial hydraulics, London, Constable & Company, Ltd., 1955, xii + 257 pp.

LELIVASKY, S., Irrigation and hydraulic design, Vol. II, Irrigation works, New York, The Macmillan Co., 1957, xvi + 864 pp. $60.00.

POINCARE, H., Les methodes nouvelles de la mecanique celeste, I., New York, Dover Publications, 1957, 382 pp. $2.75. (paperbound)

POINCARE, H., Les methodes nouvelles de la mecanique celeste, II., New York, Dover Publications, 1957, 479 pp. $2.75. (paperbound)

POINCARE, H., Les methodes nouvelles de la mecanique celeste, III., New York, Dover Publications, 1957, 414 pp. $2.75. (paperbound)

PRANDTL, L., and TEITJENS, O. G., Applied hydro- and aeromechanics, New York, Dover Publications, 1957, xiii + 311 pp. $1.85. (paperbound)

PRANDTL, L., and TEITJENS, O. G., Fundamentals of hydro- and aeromechanics, New York, Dover Publications, 1957, xvi + 270 pp. $1.85. (paperbound)

SHERA, J. H., PEAKES, G. L., KENT, A., and PERRY, J. W., Advances in documentation and library science, I, Progress report in chemical literature retrieval, New York, Interscience Publishers, 1957, xi + 217 pp. $4.75.

SOUTHER, J. W., Technical report writing, New York, John Wiley & Son, Inc., xi + 70 pp. $2.95. (paperbound)

Third U. S. National Congress of Applied Mechanics
Brown University, June 11–14, 1958

The congress program, which is to be distributed in May, will feature over one hundred papers in Applied Mechanics, including mechanics of rigid bodies, mechanics of deformable solids, mechanics of fluids and gases, thermodynamics, and heat transfer. In addition, there will be four general lectures by leading authorities.

To reduce the cost of attending the symposium to the utmost, the following all-inclusive living arrangement is offered. This covers rooms in the new West Quadrangle of Brown University and all meals from breakfast on Wednesday, June 11, through luncheon on Saturday, June 14, but NOT the Banquet on Thursday night. The rates will be $24.00 for each of two persons sharing a room, or $30.00 for a person occupying a single room. Rooms will be available without additional charge for Tuesday night and Saturday night. Please note that this arrangement was only made possible by excluding all deviating arrangements for those planning to live on the Brown campus. Those planning to stay at hotels or motels will be able to lunch in the Brown Refectory at the price of $1.50 per luncheon. The banquet ticket will be $5.00.

Registration Fees

Advance Registration on or before June 7th, $4.00
Registration on June 8th or later, $6.00

Please make checks payable to: *Applied Mechanics Congress*, not to any person.

Requests for copies of the program and letters concerning advance registration should be addressed to Miss E. M. Addison, Box F, Brown University, Providence 12, Rhode Island. In registering, please indicate number of persons in party and family relationship, desire for single rooms or willingness to share rooms, estimated arrival and departure times, and need for parking space.

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

(Continued on outside back cover)

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

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